Freiberg On-line Geoscience Vol. 3

FOG is an electronic journal registered under ISSN 1434-7512.

Hydrogeological and hydrochemical investigations in the Rioverde basin, Mexico

Britta Planer-Friedrich

Institute of Geology, university of mining and technology Freiberg

LIST OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

1. INTRODUCTION

1.1. Preamble

In May 1999 this master work was begun with the title "Origin of arsenic in groundwaters of the Rioverde basin, Mexico" to investigate on reported extremely high arsenic contents in a semiarid sedimentary basin in the central-northern part of Mexico surrounded by the volcanics of the Sierra Madre Oriental to the east and the Mesa Central to the west. The reported arsenic contents of 1 up to more than 5 mg/L would have presented a serious danger to the rural area with partly intensive irrigation agriculture and no means of water treatment neither for irrigation nor for drinking water.

To determine arsenic a special new field method was used. The main advantage of this equipment developed at the Freiberg University of Mining and Technology is its small size due to which it is possible to carry the equipment to the field and measure total arsenic and the two species As(III) and As(V) on site without having the determination uncertainties of duration and kind of sample storage. This measuring campaign in Mexico was the first field experience with the equipment.

The first field determinations of arsenic in June 1999 in a small area southwest of the main town Rioverde (El Refugio) showed significantly lower arsenic concentrations than expected with maximum values of about 10 µg/L, still a little increased compared to the average groundwater values of less than 1 µg/L.

To be sure El Refugio area was not an untypical part of the basin with these low arsenic contents about 50 wells spread all over the southern part of the basin were checked for arsenic covering roughly an area of about 50 km north-south and 30 km west-east. The maximum values found were about 40 µg/L.

Thus it could be stated definitively that the values of several mg/L reported in HOFMANN (1994) were wrong, perhaps just a mix up of units between mg/L and µg/L.

With this new information the title of the master thesis changed to "hydrogeological and hydrochemical investigations in the Rioverde basin, Mexico" and emphasis was put on two studying areas "El Refugio" southwest of Rioverde and "Pastora" northnorthwest of Rioverde plus some springs. The hydrogeological situation in the basin is especially interesting due to

- the geological situation of this basin was assumed being tectonically a young graben structure over an older cretaceous platform,
- the water quantity and quality problems of this semiarid area with intensive use of the mostly periodical surface water and the groundwater without really knowing the number, extent or depth of the aquifers endangered by overpumping, fertilizer and pesticide use since about 40 years and
- a big (yield: 4.5 m^3/s) and several smaller karst springs with an unknown, probably quite distant recharge area.

1.2. Objectives

The main objectives of this master thesis were

- collect information from previous projects, analyzing and partly reinterpreting them.

Geology

- amplify the existing geological map by field observations in selective outcrops
- sample a tuff cone in the basin for thermoluminiscence dating
- interpret the basin´s general tectonic structures
- try to model the basin´s depth from existing geophysical sections and drillings
- sketch a geological-tectonical model for the basin´s development in the Quarternary

Hydrogeology

- choose two representative distinct study areas for physicochemical analysis of the pumped well water, including trace element analysis
- investigate selected wells in these two study areas for pesticides
- take samples for isotopic analysis on Tritium and $^{2}H/^{18}O$
- measure groundwater tables and combine the results with previous measurements from other projects
- sample karst springs, for the biggest one (Media Luna) direct sampling of each of the 6 outlets by diving
- calculate the water balance for the southern part of the basin

Arsenic

- characterize the general chemical behavior, natural occurrence, contamination sources, toxicity and removal techniques of arsenic from literature
- check on the reported high total Arsenic concentrations in wells of the described area and selective in the whole southern part of the basin
- apply speciation technique for As(V) and As(III) in the selected wells
- test the new field method developed at the TU Freiberg and make suggestions for further improvement

Mapping

- present a multi-layer GIS (geographical information system) atlas with a DEM (digital elevation model) and the thematic maps topography (base map including roads, springs, rivers, drains), geology, tectonics, soil, potential use and different databases with e.g. the locations of the analyzed wells and springs, wells with determined groundwater tables, the examined geological outcrops, geophysical sites, drilling sites, etc.
- present a characterization of all the sampled wells with information on the well construction, previous chemical analysis or groundwater table determinations

1.3. Deliverables

The main deliverables of this master thesis were aimed to be:

Geology

- improve the geological and especially the tectonical idea of the basin in order to comprehend the hydrogeological settings, detect geogenic contamination sources, possible paths for anthropogenic contamination and help to make an optimum choice for new well drillings regarding well depth, well yield and water quality in the future

Hydrogeology

- develop a model about the existing aquifers, their recharge area, the composition and possible connections between the aquifers in order to distinct geogenic and anthropogenic influences on the groundwater, ascertain damage already done by man, estimate restrictions and limitations for water use and protect the aquifers in the future to reassure water quality
- calculate the groundwater recharge and development of the groundwater table to discover recharge and discharge areas and help to indicate a sustainable use of the aquifers to reassure water quantity

Arsenic

- get reliable arsenic data in order to estimate future problems for irrigation or drinking water considering the special chemical behavior and toxicity of As(V) and As(III)
- help to improve the arsenic field determination method

1.4. Abstract

The study area is part of a 4500 km^2 large sedimentary basin, the Rioverde basin, in the central-northern part of Mexico at altitudes of 1000 masl surrounded by the volcanics of the Mesa Central to the east and the Sierra Madre Occidental to the west. Average annual temperatures in the basin are approximately 21°C, precipitation is about 500 mm/a. Typical for a semiaride climate rainfall occurs in few, heavy rain events during the rainy season around September while in other months, especially February and March there may be no rainfall at all. Potential evaporation with about 1600 mm/a exceeds precipitation by far.

The biggest town, Rioverde, is located in the southern part of the basin, on the southern riverside of the river rio verde, that crosses the basin from the west to the east. Westsouthwest of the town Rioverde the area around the village El Refugio is intensively used for irrigation agriculture. The irrigation water is provided by a karst spring with a yield of about 4.35 m^3/s, the Media Luna, and approximately 600 wells, about 10 of them garantueeing also Rioverde´s drinking water supply. North of Rioverde around the village of Pastora agriculture is limited especially due to soil properties and water quality, drinking water is supplied by tanks. The whole eastern part of the basin is sparsely populated wasteland.

The most important structure for the geological development in this area and the deposition of the corresponding rocks is the platform Valles - San Luis Potosi that formed during the Appalachian (Permian-Triassic) and remained emerged during the entire Triassic and Jurassic. At the beginning of Cretaceous the platform subsided and the oldest sediments that can be found at the basin´s margins and underneath the Quarternary basin fill in the basin are Cretaceous limestones. At the transition from Cretaceous to Tertiary compressive tectonical forces from the SW related to the subduction of the Farallon plate caused the formation of a basin and range province today bordering the basin to the north and northeast. Subsequent extension enabled acid volcanic extrusions, mainly rhyoliths, today forming the basin´s eastern border.

It could be shown in this study that the sedimentary basin is a tectonical graben structure formed at the transition from Tertiary to Quarternary. The main thrust of this graben structure probably is an elongation of the Meozoic platform that was activated again. The further Quarternary development was reconstructed for the first time in this thesis. The sudden subsidence of the graben is supposed to have created a drainageless depression, filled by shallow lakes and puddles which were subject to intensive evaporation in the semiaride environment. The deposition of chalk and later on gypsum happens in this period. It is assumed that the river rio verde filled the depression rather fast with debris from the nearby Sierra creating a deltaic fan of gravel, sand and clay in the southwestern part of the basin. Later on basalts and tuffs intruded in these Quarternary sediments. The youngest deposits are caliche and travertine which were differentiated in this study. The whole depth of the Quarternary basin fill was found to be around 200 m in average, 450 m at the most.

Starting with these new ideas about geology and tectonics a hydrogeological model for the southern part of the basin was set up for the first time in a serie of many previous projects. The model was based on both hydraulic parameters as the calculations of the groundwater recharge, the catchment area and the groundwater flow direction, obtained from the interpretation of time series of groundwater table determinations, and hydrogeochemical results from the field campaign in July and October 1999. Reverse

geochemical modeling with PhreeqC2, done for 4 representative wells, proved the created model to be consistent.

Concerning hydraulic parameters the most important results are the following: Two main aquifers exist in the basin, a confined Cretaceous and an unconfined Quarternary one both interconnected without distinct aquiclud in between. The main recharge area for the Cretaceous aquifer was proven to be the Sierra west of the basin; in the basin groundwater recharge was calculated to be very low. The calculated amount of recharged groundwater for the basin´s southwestern part equals the yield of the karst spring Media Luna (4.35 m^3/s), while in the northwestern part it is only one quarter of that. The main drain in the southwestern part is the river rio verde causing a general groundwater flow for both aquifers from the west to the east, while in the northwestern part the shallow groundwater (Alluvium) flow it is from the east to the west, probably due to the influence of the graben fault zone with higher permeability.

No man made declining of the groundwater table was detected in Pastora area, while severe drawdown of -10 to -15 m from 1972-1997 was documented for El Refugio. South of El Refugio, near El Jabali, several former dug wells are dry and new wells have been drilled with watertables 4-15 m below the bottom of the old dug wells. This is consistents with reports of former wetlands that are cultivated farmland nowadays and indicates drawdown of the groundwater table over a large area.

For detailed chemical investigations (main ions, trace elements, isotopes, pesticides) two distinct areas were choosen, El Refugio and Pastora. Observations from previous projects were confirmed for Pastora area with high mineralization and Ca^{2+} and SO_4^{2-} concentrations close to gypsum saturation resulting from the contact with Quarternary evaporites. Considering El Refugio reported low mineralization and a predominancy of Ca^{2+} and HCO_3^- could only be confirmed for the deep wells tapping Cretaceous groundwater but also Quarternary groundwater through leakage conditions or due to the fact having a screen in both Quarternary and Cretaceous aquifer. Shallow wells in El Refugio show the influence of Quarternary evaporites, yet not as high as in Pastora.

The system of karst springs with the biggest karst spring, Media Luna, it´s smaller neighbour Anteojitos (0.25 m^3/s) and Ojo de Agua de Solano, the spring of the river rio verde, are characterized by increased concentrations of Ca^{2+} and SO_4^{2-} supposed to result from the contact to a Cretaceous gypsum formation (Guaxcama) at the bottom of the Cretaceous limestone. The idea that the 6 different outlets from the karst spring Media Luna spill water from different horizons or aquifers was disproved by direct sampling of the outlets by scuba diving.

The reported high arsenic concentrations of 1-5 mg/L that originally were the main point of concern fortunately were neither confirmed in the above described wells and springs nor in about 30 further wells spread all over the southern part of the basin. A new method for determining both total arsenic and As(III) directly on-site was tested and though some handicaps like handling, reaction time and calibration, especially for speciation, still have to be improved, the equipment was proved to work in general. Comparison with laboratory HGAAS showed a maximum negative deviation of -5.6 µg/L and a maximum positive deviation of +2.2 µg/L.

Increased pesticide concentrations, especially DDT (2-6 μg/L) as well as α, β, γ-HCH (0.08-1.1 μg/L), heptachlor (0.02-0.2 μg/L), dieldrin (0.03-0.4 μg/L), aldrin (0.05-1 μg/L) and endrin (0.06-0.3 μg/L), in all of Rioverde´s drinking water wells, except for the youngest well San Diego drilled in 1999, remain the most severe concern from the chemical part of this study.

The presentation of the geological and hydrogeological results (mapping part of this thesis) was not done in the traditional way of printed maps, but as multi-layer digital atlas (supplied on a 650 MB CD) containing the vector objects geology (basis information taken from existing geological maps, checked at about 85 outcrops and modified), tectonics and watersheds/flowpaths, the raster objects digital elevation model (DEM), various false color Landsat images, soil classes and potential land use maps and a contour map with the depth of the Quarternary basin fill as well as numerous databases about the geological outcrops, drillings, geophysics, rock samples, meteorological stations, river flow gauges, groundwater tables from 1972-1999, pumping tests, hydrogeochemical results from July and October 1999 and arsenic concentrations in the whole southern part of the basin.

Additionally detailed description for all the wells and springs sampled during the field campaign was performed collecting information about the location, environment and use of the wells, well depth, yield and construction, well equipment, operation, time series of groundwater tables and previous hydrogeochemical analysis.

1.5. Acknowledgement

Surely my field work in Mexico was not always trouble-free, but nevertheless it was the most interesting and instructive time at the end of my study thanks to the following people.

- **Prof. Dr. Broder. J. Merkel** from my home university in Freiberg, who initiated this diploma work in Mexico, helped me with the pre-organisation, visited me in the field in July 1999 and was always available for discussions, suggestions for improvement and help with all technical problems (especially computer programs)
- **Dra. Maria Aurora Armienta** from the University of Mexico City (UNAM) who was not only specialist in all Chemistry related subjects, especially Arsenic, provided laboratory facilities for preparing my own field equipment and analyzed all my samples with her laboratory staff, but who also showed endless patience with airport customs, immigration offices and me...
- **M.Sc. Antonio Cardona**, the "man on-site" who initiated all the contacts to the local authorithies and got never tired neither of hydrogeological discussions (the pumping tests...), long night rides to San Luis nor a rainy field trip.

Special thanks to **Prof. Dr. P. Udluft** from the university in Würzburg, Germany, who took the bother to expertise this work.

Thanks also to
- **SASAR**, the local water authorithy in Rioverde, for providing me access to all their wells, their data and for their contact to laboratory of the Rioverde University. Special thanks to José Antonio, Malle and Morris for accompanying me on various field trips and Morris also for his figurative trials in teaching me Spanish.
- numerous people from **INEGI** (Instituto Nacional de Estadistica, Geografía e Informática) in Mexico City and San Luis Potosi, **Secretaria de Ecologia** in Rioverde and San Luis and the **CNA** (Commission Nacional de Agua) in Rioverde and San Luis Potosi, who provided me valuable information and any kind of help.

and from Germany
- **Dipl. Chem. P.Volke** (university Freiberg, hydrogeological section) for introducing me to the Arsenic field determination, providing me his data and for numerous later discussions
- **Mr. H. J. Peter** (university Freiberg, hydrogeological section) for the nuisances with my pesticide analysis
- **Prof. Dr. D. Hebert** (university Freiberg, institute for physics) for the Tritium analysis
- **Prof. Dr. M. Geyh** (BGR Hannover) for Deuterium/Oxygen determination
- **Prof. Dr. Dudel** and **Mr. Dipl. Chem. A. Weiske** (TU Dresden, institute for ecology, Tharandt) for the ICP-MS analysis
- **Dr. M. R. Krbetschek** (Saxonian Academy of Science) for the thermoluminiscence preparation

Besides the subject related contacts I met many people in Mexico who showed me hospitality and friendship, like Ofelia Morton and her family Jaime, Rodrigo and Pablo; Jorge and Miguel Cardona, Leobardo and Mario and many people in the field who invited and fed me despite of all the language problems but most of all the Cardona family in Rioverde, who not only gave me a home for about 3 months and supported me in every new "catastrophy" but also taught me "not to pay any attention" whatever problem may occur and always assured me "we´re happy to have you here"...

....muchas gracias à Gloria, Antonio y Vidal Cardona

2. BACKGROUND

Chapter 2 provides a summary of existing knowledge concerning the study area obtained from literature and previous projects.

2.1. Introduction to the study area

2.1.1. Physiography

The study area covers the southern part of the Rioverde basin, physiographically located in a region named Sierras Bajas de la Sierra Madre Oriental in the central-northern part of Mexico, approximately 120 km ESE´ of San Luis Potosi, capital of the state with the same name (Fig.1 and Fig.2).

Fig. 1 Mexico´s political division - red square shows the Rioverde basin in the state San Luis Potosi (http://www.inegi.gob.mx 1999)

The entire basin measures approximately 4.500 km^2 and is morphologically easily recognizable by the mountain chain of the Mesa Central (Altiplano Mexicano) to the west (100°06´) with maximum altitudes of more than 2500 masl (meter above sea level) and the foothills of the Sierras Altas de la Sierra Madre Oriental to the east (99°48´). To the north the basin extends relatively flat to approximately 22°30´ (Granjenal) showing some elongation to the northwest towards a second smaller basin including the towns of Villa Juarez and Cerritos finally being bordered much further in the north by the Sierras Atravesadas. The southern limitation (21°45´) is also marked by a morphological elevation yet not as clearly, further to the south the Mexican neovolcanic belt follows.

.

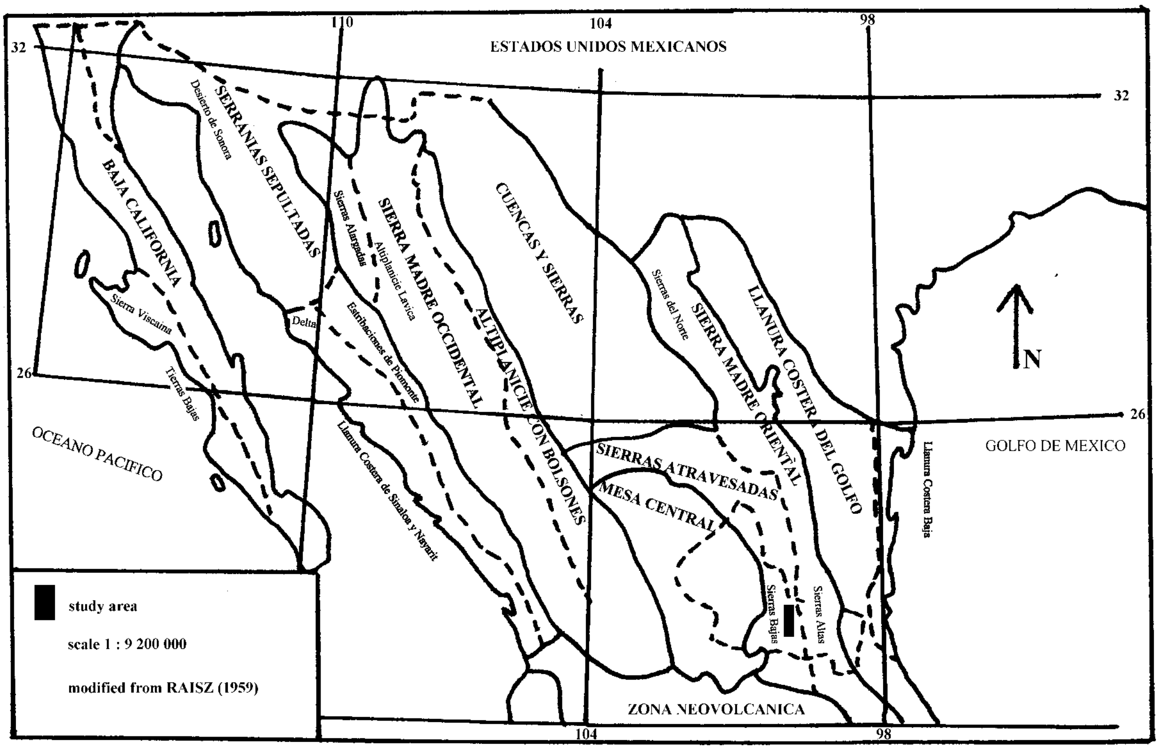


Fig. 2 Mexico´s division in natural regions - black square shows the Rioverde basin between the Sierras Bajas and Sierras Altas of the Sierra Madre Oriental (modified from RAISZ 1959)

The main town Rioverde in the southern part of the basin (meteorological station Rioverde N 21°55´30´´, W 99°58´44´´) has an altitude of 989.9 masl, the medium altitude of the entire basin is 1000 masl. Minor elevations in the basin like small hills near El Jabali, Palomas, San Francisco, Sta. Rita and Pastora reach altitudes of no more than 400 m above the basin floor.

2.1.2. Climate

The climate of this region is semiarid (Fig.3), classified in the climatic map ("carta de climas de Queretaro" No.14 QIII) according to Koeppen as BShwg (B = arid climate, S = steppe like vegetation, h = mean annual temperatures of more than 18°C, w = precipitation mainly in summer, g = maximum temperature in spring just before rain period).

In the digital tntmips atlas [file hydrology, meteo_stations] the location of the 5 different meteorological stations in the Rioverde basin is illustrated. Tab.1 lists maximum and minimum values for temperature and precipitation calculated as averages from all the years registered in these stations and Fig.4 shows the climate time series. The corresponding data are displayed in App.No.1, App.No.2 and App.No.3.

The temperature course of all the meteorological stations shows a maximum in May/June and a mimimum in January. Most of the precipitation (from >100 up to almost 300 mm/month in single months) falls in few heavy events in two rainy periods, one in June/July the second (more important one) in September. The driest period is around February and March with rainfall less than 20 mm per month, sometimes just 1-5 mm.

Fig. 3 Mexico´s climatic regions - red square shows the Rioverde basin in the aride dry zone (http://www.inegi.gob.mx 1999)

Tab. 1 Average precipitation and temperature from 5 different meteorological stations in the Rioverde basin

meteorological station	precipitation [mm/a]	max. precipitation [mm/month]	min. precipitation [mm/month]	max. temp. [°C]	min. temp. [°C]	mean temp. [°C]
Pastora	416.7	68.4 (Sept.)	7.6 (Feb.)	24.9 (June)	16 (Jan.)	21.0
Rioverde	509.5	95 (Sept.)	5.6 (Feb.)	25 (June)	15.7 (Jan.)	20.9
Media Luna	577.4	107 (Sept.)	2.4 (March)	26.5 (May)	15.6 (Jan.)	21.9
Ojo de Agua Seco	628.4	121.3 (Sept.)	10.1 (Feb.)	25.5 (May)	15.5 (Jan.)	21.2
El Huizachal	616	100 (Sept.)	11.9 (Feb.)	24.2 (June)	16.1 (Jan.)	20.8

Besides these general correspondences the meteorological data differ concerning the absolute precipitation values. Compared to the northern part (Pastora) the southern part of the basin (El Huizachal, Ojo de Agua Seco) gets more annual rainfalls and heavier rain events in the rain period. The temperature distribution is more or less the same at all 5 stations.

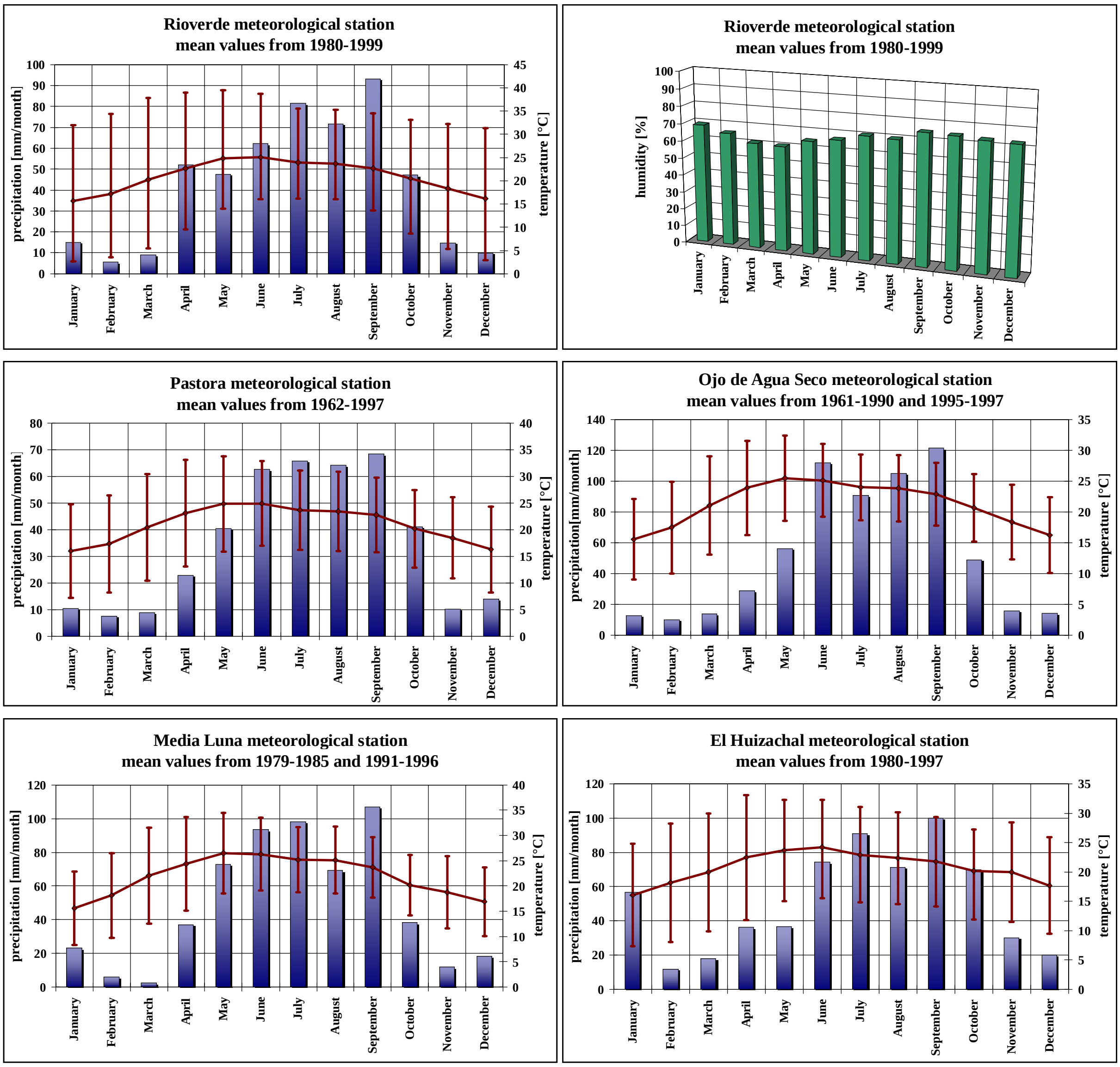


Fig. 4 Climate courses of 5 different meteorological stations in the Rioverde basin (red line = average monthly temperature with maximum and minimum day temperatures indicated as deviations, units on right y-axis, blue columns = precipitation, units on left y-axis)

2.1.3. Hydrology

Due to the semiarid climate most of the few smaller rivers are periodical streams, infiltrating already to the plains (Fig.5). Only a few are contributing to the main stream, the "rio verde" (green river) crossing the open basin from the west to the east getting its base flow from the spring "Manantial Rio Verde" (= La Taza, see Appendix / Mapping, well and spring description) located in the village La Reforma at an altitude of approximately 1020 masl, just about 15 km west of the town Rioverde. Further upstream water flow occurs only in the rainy season. At the eastern margin of the basin the rio verde turns to the southeast, joining later with the Panuco stream running to the Golf of Mexico.

Fig. 5 Dry river bed of the river Morales (near P16 / P17) in July 1999

2.1.4. Agriculture

Some karst springs, the biggest of them being the "Media Luna" with an average permanent yield of 4.35 m^3/s, and mainly groundwater serve the needs of an intensive irrigation agriculture in a wedge-shaped area from Rioverde to the west. Mainly corn, oranges and lucerne, but also chili, tomatoes, peanuts, sweet potatoes, sweet cane and beans are grown here all over the year (Fig.6). In the northern and eastern part agricultural use is limited mainly due to infertile soils but also because groundwater salinity exceeds the plant´s limit of tolerance (digital tntmips atlas [file topography, potential use]).

Fig. 6 Agriculture in the Rioverde basin - above: most important crops: oranges, mais and chili; right: traditional ploughing with oxes

2.1.5. Vegetation

The natural vegetation are mezquites, cactus, huizaches, gobernadoras, pithayos and zacates. Large areas, especially in the eastern parts of the study area are almost without any vegetation. The bare, dry soil is covered with short light green grass only for some months during and after the rainy period. The traditional mezquites are more and more replaced by intensive agriculture since they grow on humus rich, deep and therefore very fertile soils (Fig.7).

Fig. 7 Typical landscape near Pastora

2.1.5. Infrastructure

Since 1955 until a few years ago the town of Rioverde (1995: 44.226 inhabitants, 2.01% of the state of San Luis, TACSA 1998) has been an important center for processing mining products from the fluorite mines El Refugio and El Realito (40 km southwest of Rioverde in the state of Guanajuato, N 21°34´12´´, W 100°10´42´´, at 1226 masl). According to the homepage of the mexican mining information center (http://www.mexmin.com/) 110,643 tons of fluorite have been processed 1990 and 170,640 tons were scheduled for 1991. The mining declined and is abandonned nowadays, however no precise data were available. The only other important branch remained in Rioverde is an industry for processing citrus fruits. The main economic branch today is crop growing and service industry for the rural area.

2.2. Geology

2.2.1. Geological Overview

The Rioverde area is a sedimentary basin filled with Quarternary sediments of unknown depth and stratification. In the southwest it is surrounded by a Tertiary rhyolithe massive extending about 100 km further to the west. Some massive Cretaceous limestone hills border the basin to the northwest. In the north long narrow ridges also of Cretaceous limestone stretch from the northwestern to the northeastern part of the basin changing their strike direction from NW-SE in the north to NNW-SSE in the east. Theses ridges and the corresponding valleys, according to the official map (1:250,000) filled with Tertiary conglomerates, present a basin-and-range province well developed northeast of the basin. In the basin´s southeastern border the geology is more variable, Tertiary rhyolithes, conglomerates and Quarternary basalts alternate with Cretaceous limestones (Fig.8).

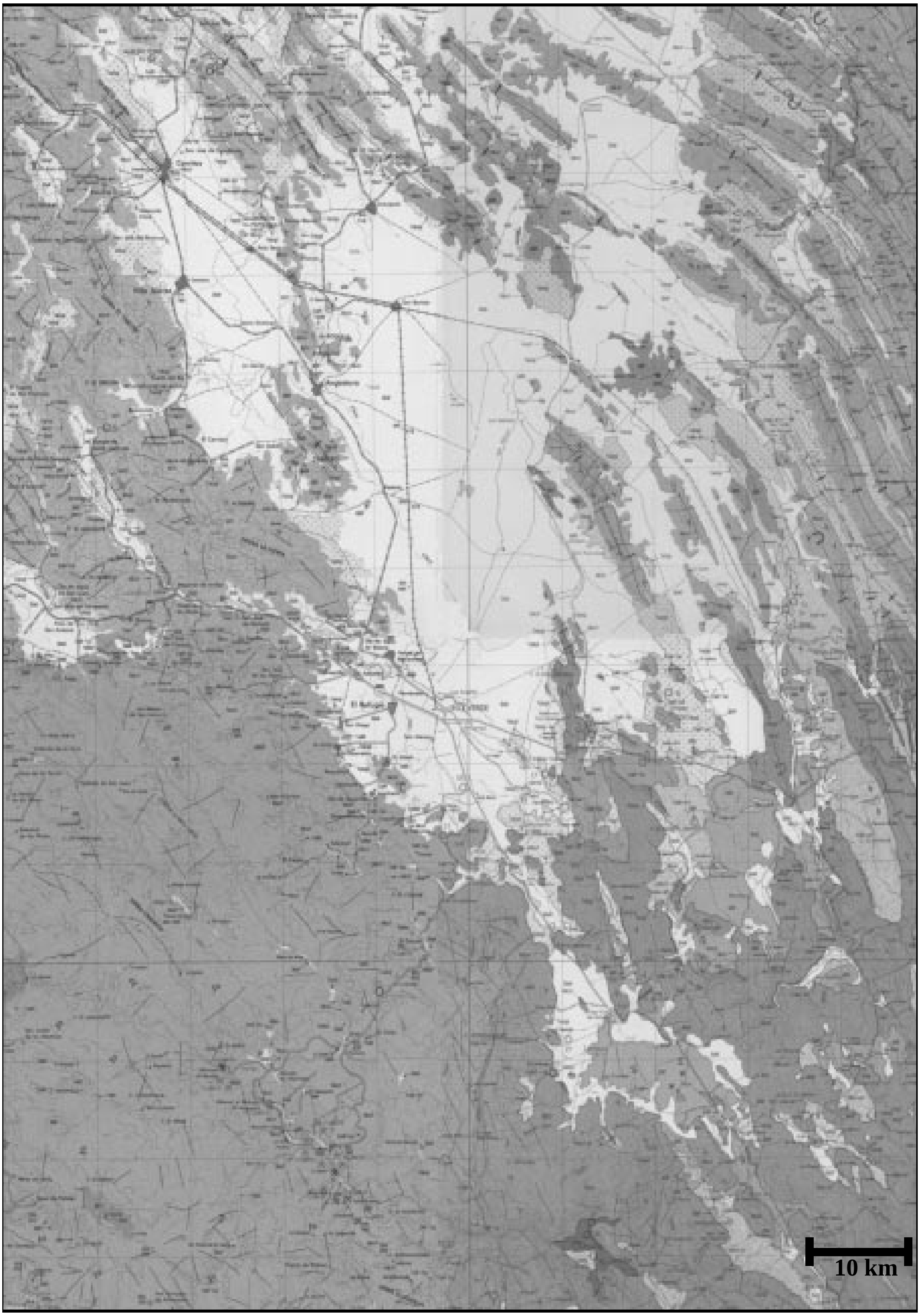
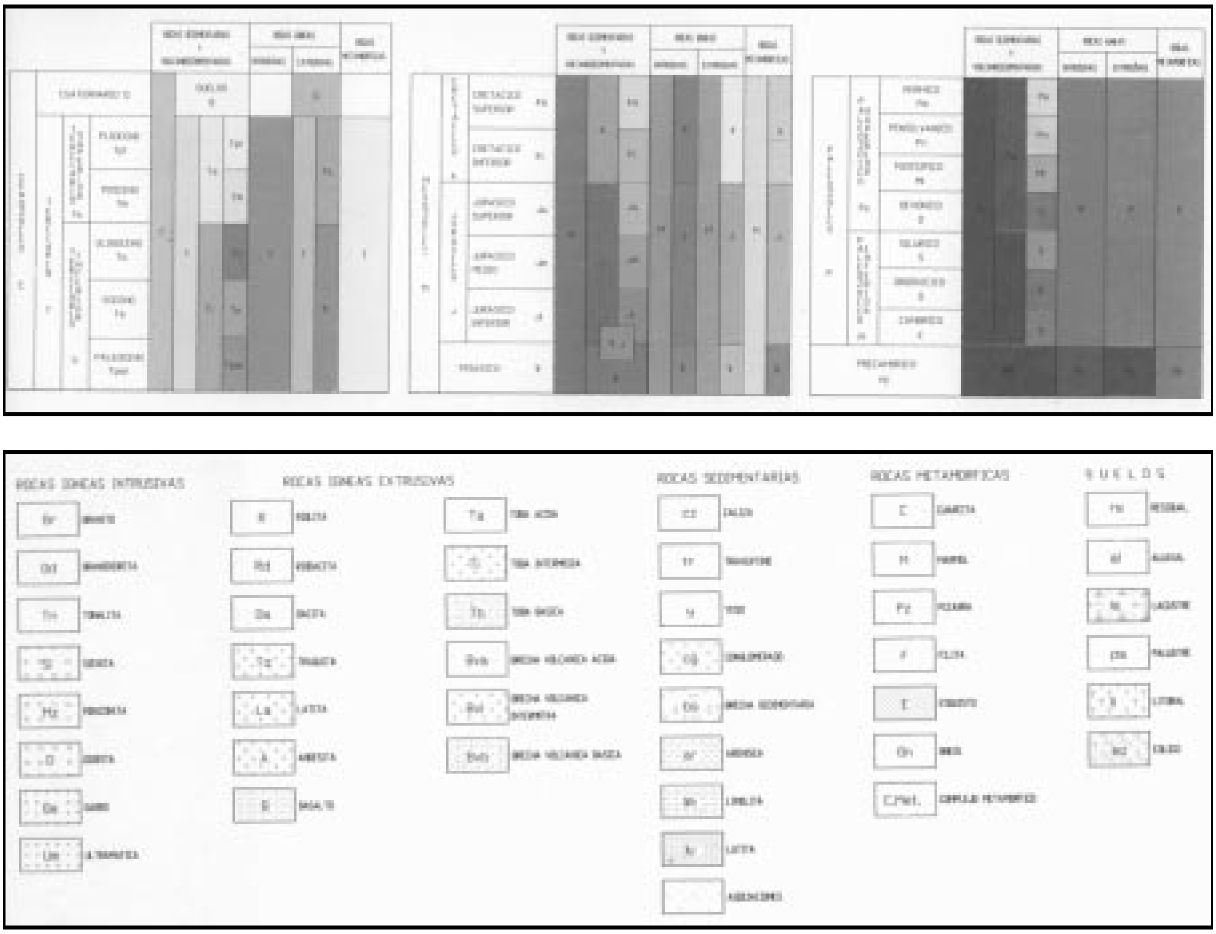


Fig. 8 Geological map reduced in scale from the Carta Geologica 1:250,000 (CETENAL 1983)



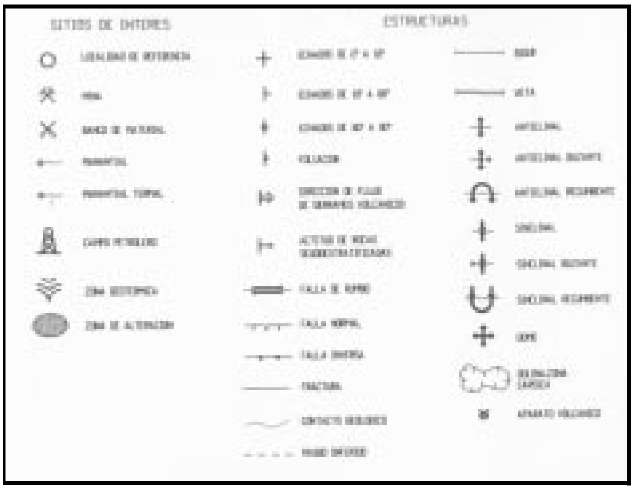


Fig. 9 Legends for the geological map 1 : 250,000 (CETENAL 1983)

2.2.2. Geological development

2.2.2.1. Palaeozoic age

Only very scarce outcrops in the entire northeastern Mexico reveal something about the palaeozoic basement in this area but it is supposed to be the southern elongation of the Ouachita geosyncline from the southeastern United States formed as a consequence of the proto-Atlantic´s closing. The corresponding rocks are fractured and folded Precambrian, Palaeozoic and Triassic metamorphites like shists, gneis and metaconglomerates (MORÁN-ZENTENO 1994).

2.2.2.2. Mesozoic age

2.2.2.2.1 Triassic

Connected to the Permian-Triassic orogeny (Appalachian) the platform "Plataforma de Valles - San Luis Potosi" was formed as a crest between the geosyncline of the Golf of Mexico ("Antiguo Golfo") and the central Mexican basin ("Cuenca Mesozoica") (MORÁN-ZENTENO 1994). This platform, with the study area located in its southwestern part, is the most important structure for the geological development during the entire Mesozoic (Fig.10).

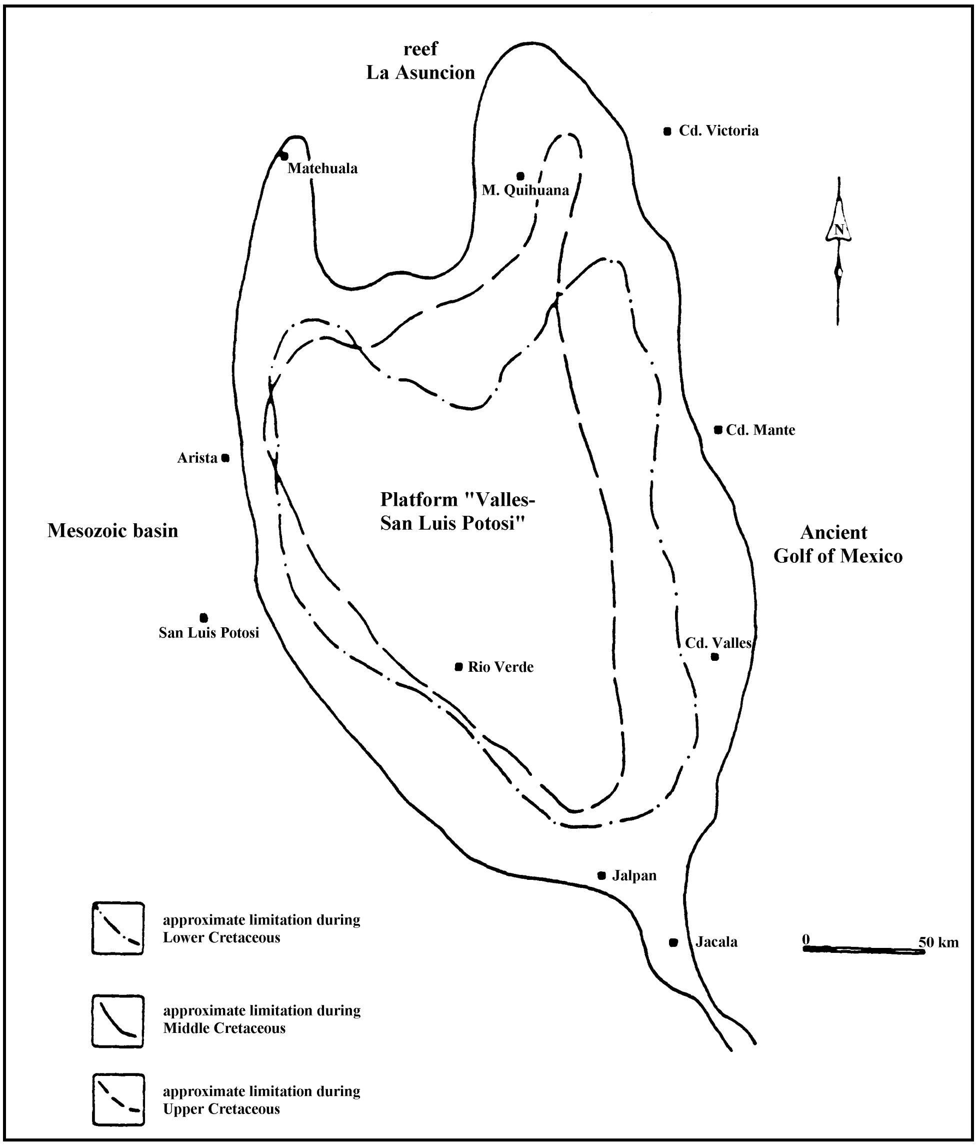


Fig. 10 Development of the platform Valles - San Luis Potosi during Cretaceous (CARRILLO 1971)

2.2.2.2.2 Jurassic

During Jurassic marine influence with pelagic sedimentation was widespread in the geosynclines compared to the more neritic environment on the platform. Some single shallow marine transgressions took place, but in general the continental sedimentation in massive troughs was predominant (MORÁN-ZENTENO 1994). Even the first big transgression in the Upper Jurassic intruding from the east related to the western opening of the Tethys and the disintegration of Pangea, did not affect all parts of the platform.

Most areas of the platform remained emerged during the entire late Jurassic (MORÁN-ZENTENO 1994). Today no Jurassic sediments outcrop in the study area.

2.2.2.2.3 Cretaceous

At the beginning of the Cretaceous due to some initial subsidence a transgression took place over the entire platform filling basins between the last elevated parts. The oldest sediments found in the Rioverde basin are from Aptian. At this time probably shallow, warm and clear water covered this area separated from the open sea through a barrier (CARRILLO 1971). Under these conditions in a semiarid environment evaporation exceeded the fresh water supply causing the formation of chemical sediments of the Guaxcamá sequence.

This sequence was first described 1933 by K.Goldschmid at the typus locality "Zona de Yesos" (gypsum zone) in the sulfur mine Guaxcamá, 25 km SW of Cerritos. Light to dark gray anhydrites and gypsums in 5-40 cm thick layers are interbedded with few clay layers. 10-50 cm layers of fractured dark gray dolomite and in the lower part layers of microcristalline light gray limestones and dark gray dolomites indicate subsidence movements in which the barrier disappeared, fresh sea water intruded and the salt concentration was diluted (CARRILLO 1971). Some clastics in this evaporitic sequence correspond to seasonal changes when in winter time the rivers contained more yield to dilute the salt concentration and more sediment load of fine detritus (BORCHERT & MUIR 1964 cited in ALVARADO 1973). The entire thickness is stated to be 520 m (ALVARADO 1973), but the lower contact is not visible in the entire area.

From Albian to Cenoman further subsidence of the entire platform took place, followed by a slow but continuous marine transgression that covered even the last remaining crest (MORÁN-ZENTENO 1994). The resulting carbonatic sediments proceeding concordant over the Guaxcamá sequence are known as El Doctor, from the mining district El Doctor 25 km NW of Zimapan, Hidalgo, first described by WILSON et al. (1955).

3 (ACUAPLAN 1984) respectively 4 (LOPEZ 1982, LARA 1980) different facies are known, as there are:

- **La Negra**, a compact, cryptocristalline dark to light gray limestone and dolomites sometimes with black limestone lenses of 1-15 cm, interbedded with redish lutites. According to ACUAPLAN (1984) the whole thickness is around 30 m. LARA (1980) mentions 10-20 cm thick chert bands and interprets it to be the deepest water facies, ALVARADO (1973) also mentions oolithes belonging to this deep water facies but he doesn´t make the facies distinction.
- **San Joaquin**, also a cryptocristalline, compact, dark gray limestone in layers from a few to 35 cm, with a total thickness of 60 m maximum (ACUAPLAN 1984). LARA (1980) describes moreover thick black chert banks and an abundance of rudists (Toucasia Spp., Requienia Spp.), ALVARADO (1973) names gasteropodes and many microfossils.
- **Cerro Ladrón**, 10 cm - 2 m thick, tabular reef limestones deposited in shallow water environment, sometimes fractured without preferential direction. LARA (1980) only states sporadic layers of fossil fragments and rare chert.

- The forth facies, missing in the description of ACUAPLAN (1984), is **Socavón** with calcareous rudites (in angular fragments from 0.25 cm to 20 cm) in compact, gray limestones with a 1.5 - 6 m thick stratification, containing in parts much black chert. LOPEZ (1982) also mentions conglomerates; ALVARADO (1973) describes the occurrence of clastic sediments from back and forereef areas.

Today most of the El Doctor limestones and dolomites show solution marks and stylolithes, sometimes also signs of recristallization. The entire thickness of the El Doctor sequence varies in literature from 200 to 800 m at maximum (LOPEZ 1982), 1800 m (ALVARADO 1973) and 1000-2000 m (SECRETARIA DE AGRICULTURA 1980).

As first indications of the Laramidian orogeny from the Cenomanian on the eastern part of the platform subsided while the western part was uplifted due to strong deformation forces implied by the subduction of the Farallon plate under the western continental portion of Mexico. The sea retreated to the east associated with prograding deltas from the west (MORÁN-ZENTENO 1994). The corresponding sequence deposited discordant over El Doctor during Campanian to Maastrichtian is named Cárdenas and contains continental clastic flysch sediments (CARRILLO 1971).

The typus locality for this sequence is located in the Cárdenas syncline near the train station of the same name, first described by Bose 1906. The discordant contact to El Doctor is marked by a basal conglomerate cemented with calcareous cement, frequently forming small barrier springs (ACUAPLAN 1984). Statements for the sequence´s thickness vary from 1055 m thick for the total sequence (MYERS 1968 cited in de la PENA 1994) to detailed descriptions of 50-500 m (LOPEZ 1982) respectively 1180 m (ACUAPLAN 1984) of lutites, arenites and biosparites followed by 200-300 m (LOPEZ 1982) respectively 445 m (ACUAPLAN 1984) of lutites and siltstones and finally terminated by 300-500 m (LOPEZ 1982) respectively 400 m (ACUAPLAN 1984) of siltstones, arenites and biosparrudites.

2.2.2.3. Neozoic age

2.2.2.3.1 Tertiary

From Campanian / Maastrichtian to the beginning of Tertiary (Eocene-Oligocene) the compressive regime of the main folding phase produced NW-SE (290-320°) striking narrow folds in the Sierra Madre Oriental (LABARTHE 1989), wider valleys and less narrow anticlines in the Mesa Central perhaps due to the existence of the stable cratons of Coahuila platform and Taumalipas Peninsula at this time acting as a counter weight in the N-NE against the deformation forces from the SW (MORÁN-ZENTENO 1994). A change of movement in the tectonic plates when the North American and Farallon plates formerly converging oblique in western Mexico began to move frontally at each other with greater velocity caused the Cretaceous platform to subside to the west. Triggered by this entire rock stacks were folded and began to collapse their sliding being facilitated by the Cretaceous evaporitic layers acting as a decollement surface (MORÁN-ZENTENO 1994).

As recovery from the compressive phase an extensive regime started initiating the Tertiary volcanism with its main activity in Oligocene and Miocene. The Rioverde basin suffered from significant subsidence, limited by NW lineaments, forming a graben structure; Tertiary sedimentation began (LABARTHE 1989).

The main volcanic rocks are rhyolites with an age of 26.7-30.9 ± 0.4 Mio.years (K-Ar dating TUTA et al. 1988), 29.1-30.2 ± 0.3 Mio.years (K-Ar dating RUIZ et al. 1980), 30.58 ± 0.43 Mio.years (K-Ar dating LABARTHE 1989) respectively 32.7 ± 2.4 Mio.years (Rb-Sr dating RUIZ et al. 1980). These gray to red(ish) rhyolites are often strongly fractured with a pseudo-stratification, 70-90 m thick and show a porfirical structur with alcaline feldspar (Sanidine) and quarz phenocristals, only few alterated biotites and some accesories like zircon and opac minerals bedded in an aphanitical feldspar-quarz matrix (de la PENA 1994). Due to similarity in age and chemical composition these rhyolithes are supposed to be part of the high potassium calc-alcaline province just east of the main calc-alcaline Sierra Madre Occidental (RUIZ et al. 1980).

This magmatic activity was often associated with hydrothermal mineralization. In northern Mexico magmatic activity began 140 Mio. years ago and moved to the southeast until about 40 Mio. years ago. The related hydrothermal mineralizations formed belts along the eastern margin of the Sierra starting with Cr-Ni and Cu-Mo-Fe-(Au) (40-80 Mio.years ago), Zn-Pb-Cu-(Au-Ag) and Au-Ag (50-25 Mio.years ago) (Fig.11).

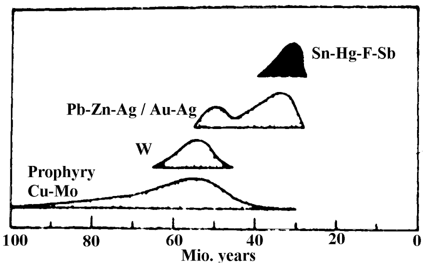


Fig. 11 Change of the composition of hydrothermal minerals with time (TUTA et al. 1988)

From the late magmatic phase (30 Mio.years ago) few and less important Sb and Hg deposits are known, more than 1000 very small, economically marginal Sn deposits and very numerous fluoride mines including some of the largest in the world (Las Cuevas, La Consentida, El Realito and El Refugio; Fig.12) (TUTA 1988).

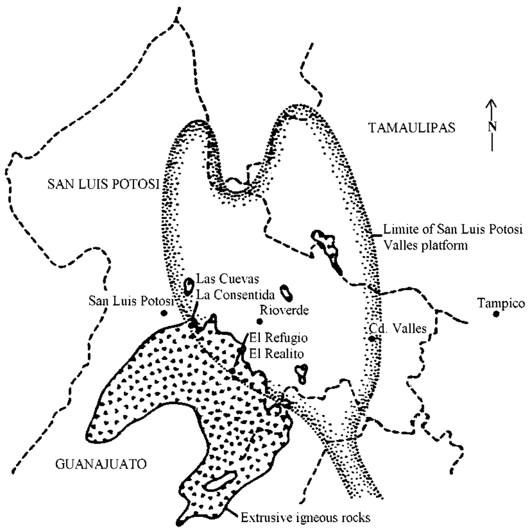


Fig. 12 Location of the most important fluoride mines in San Luis Potosi and Guanajuato (left) (RUIZ et al. 1989)

The Las Cuevas fluorite mines are located about 80 km west of Rioverde and the fluorite district El Realito and El Refugio about 45 km southwest of Rioverde. There the fluorite deposits are hosted by reef forming Cretaceous limestones from the El Doctor sequence in contact with Tertiary rhyolite breccias. This type of deposit is called replacement deposit. Meteoric waters caused the solution of limestone, creating karst features e.g. caves. In contact to hot rock the meteoric waters were heated to 60-130°C and mixed with fluorine rich fluids from volcanic rocks. The initial solutions were acid due to a lack of calcite and the presence of kaolinite as alteration product of the surrounding rock. With an increase in pH, a temperature decrease and the solution of calcium from the El Doctor limestone fluorine was deposited as the mineral CaF_2 filling the solution caves in the limestone. $^{87}Sr/^{86}Sr$ examinations showed that all Ca was derived from the limestone. Inclusion in the fluorite often show also increased contents of other elements like Fe-, Mn-oxides, Mg, S, Si, P, K, Al, Ba, As, Sr, La from the rhyolithe (RUIZ et al. 1980).

The hydrothermal influence in the Rioverde basin is proved by HOFMANN (1994) who examined 4 samples of a greenish-yellowish-brownish alteration product with a sharp contact to the gray limestones of El Doctor formation in an outcrop in La Reforma, about 7 km east of Rioverde, by x-ray diffractometry. He found the following mineral composition:

sample 1: Quarz SiO_2 > Cryolithionite $Li_3Na_3Al_2F_2$ > Albite $(Na,Ca)(Si,Al)_4O_8$ > Santafeit $NaMn_3(Ca,Sr)(V,As)_3O_{13}*4H_2O$ > Tyrolite $(CaCu_5(AsO_4)_2(CO_3)(OH)_4*6H_2O$ > Adamine $Zn_2(AsO_4)(OH)$

sample 2: Quarz SiO_2 > Zapatalite $Cu_3Al_4(PO_4)_3(OH)_9*4H_2O$ > Chiavennite $CaMnBe_2Si_9O_{13}(OH)_2*2H_2O$ > Cryolithionite $Li_3Na_3Al_2F_2$ > Albite $(Na,Ca)(Si,Al)_4O_8$ > Tyrolite $(CaCu_5(AsO_4)_2(CO_3)(OH)_4*6H_2O$ > Adamine $Zn_2(AsO_4)(OH)$

sample 3: Quarz SiO_2 > Chiavennite $CaMnBe_2Si_9O_{13}(OH)_2*2H_2O$ > Cryolithionite $Li_3Na_3Al_2F_2$ > Tyrolite $(CaCu_5(AsO_4)_2(CO_3)(OH)_4*6H_2O$ > Sanidine $(K,Na)AlSiO_8$ > Adamine $Zn_2(AsO_4)(OH)$ > Santafeite $NaMn_3(Ca,Sr)(V,As)_3O_{13}*4H_2O$

sample 4: Quarz SiO_2 > Chiavennite $CaMnBe_2Si_9O_{13}(OH)_2*2H_2O$ > Cryolithionite $Li_3Na_3Al_2F_2$ > Albite $(Na,Ca)(Si,Al)_4O_8$ > Tyrolite $(CaCu_5(AsO_4)_2(CO_3)(OH)_4*6H_2O$ > Adamine $Zn_2(AsO_4)(OH)$ > Zapatalite $Cu_3Al_4(PO_4)_3(OH)_9*4H_2O$

Mn, Li, Al, Sr, As, F and Cu bearing minerals like Chiavennite, Cryolithionite, Santafeit, Tyrolite and Zapatalite are the main indicators for the hydrothermal influence with the elements originating from the rhyolithes. Ca probably derives only from the El Doctor limestone like in the replacement deposits Las Cuevas and El Realito.

De la PENA (1994) reports that more or less at the same time of the rhyolithes origin (Oligocene-Miocene) "glass tuffs" were deposited. They show concoidal structures on fracture surfaces, approximately 80% alcaline feldspar, <20% plagioclase, some quarz, <1% mafic minerals and opac minerals. The texture is fluidal with a preferential mineral alineation. The glass matrix contains only a few cristal fragments of volcanic glass, alcaline feldspar, plagioclas and microlithos of quarz and chlorite. The occasional redish color is due to the oxidation of goethite, limonite or hematite.

Younger volcanic products cover black massive, sometimes vesiculous olivine-basalts of 25 m thickness (LABARTHE 1982), with an intergranular porfirical texture, phenocristals of calcareous plagioclase (labradorite), olivine, clinopyroxene (augite) and accessories (apatite and opac minerals) in a matrix of feldspar, plagioclase and pyroxene (de la PENA 1994). No exact age dating of these basalts has been found. De la PENA (1994) reports them to belong to the Miocene-Pliocene age since they are overlying Oligocene rhyolithes, LABARTHE (1989) proposes Upper Oligocene to Miocene correlating them with the basalts on the map San Francisco that are overlying a rhyolith of 26.8 ±1.3 Mio. years. But LABARTHE (1989) already questions if the basalts could also belong to the Pliocene to Pleistocene age (chapter 4.1.3.3).

2.2.2.3.2 Quarternary

Subsequent to this Tertiary volcanism LABARTHE (1989) states a rapid uplift for the Rioverde area and Quarternary sediments filled the basin with a maximum reported thickness of 350 m, 184 m under the city of Rioverde, 100 m in the western part of the village El Refugio and only 30 m on the right side of the river rio verde in the central eastern part of the basin (LOPEZ 1982).

Probably at the beginning of the Pleistocene a lacustrine environment predominated in the basin. Fine lacustrine sediments in the central part of the basin between San Bartolo and Rioverde on the left side of the river, in the Subbasin San Ciro and in the intermountainous valley of Palomas and La Libertad indicate this (LOPEZ 1982). LABARTHE (1989) infers moreover that lacustrine silt and clay sediments E of El Jabali forming an impermeable barrier for the groundwater circulating in solution veins in the El Doctor limestone cause with an increase in pressure level the outflow of the big karst spring Media Luna.

The environmental conditions in the basin must have changed in the course of the Pleistocene, the lake(s?) disappeared and the river rio verde cut its way (again?) through the basin. An outcrop near San Martin proves this change. There a 2-3 m thick gravel layer (with fragments of 5-40 cm size) was deposited above sand and silt from lacustrine environment (LABARTHE 1989). These fluvial sediments occur all over the southern part of the valley, the carbonatic and rhyolithic components sometimes being weakly cemented with calcareous cement. The angular components of 10-50 cm even up to 1 m size in the western part decreasing to a size of just a few mm in the eastern part (de la PENA 1994) show short transportation distances from the near Sierra in the west and a rapid deposition (ACUAPLAN 1984).

An interesting feature in the basin is caliche, a chemical sediment, building hard covers from carbonatic concretions in any geological time but mostly only recognizable from Pleistocene or Holocene. It forms under semiarid conditions (200-600 mm/a precipitation) either when precipitation containing calcium and carbon infiltrates in the soil where due to changes in pH and temperature the carbonate precipitates as concretions or when in very dry season evaporation from groundwater occurs due to low depth of the groundwater table, and calcium and inorganic carbon are transported from the groundwater to the soil horizons. Mostly some soil residuals can be detected in the Caliche. There have been some misunderstandings with the word "calizas" in Spanish, since it means on the one hand just limestone, but is on the other hand also used for this special calcareous concretion "caliche". LOPEZ (1982) reports e.g. that Caliche was found in large areas on the left side of the rio verde; this was not confirmed during the field trip in 1999. Maybe the supposed "Caliche" layers were Quarternary chalk layers.

A very recent (Holocene) deposition is the white to yellowish porous travertine all along the river and around the karst spring Media Luna and Anteojitos, due to degassing of CO_2 and consequently following precipitation of calcite. Nowadays the formation of this chemical sediment decreased due to the man made canalization of the calcium rich spring water (de la PENA 1994).

Tab. 2 Stratigraphy (according to LOPEZ 1982, amplified by the special strata for Rioverde basin)

System		group	subgroup	Rioverde zone	platform Valles – SanLuisPotosi	Mexican Geosyn-cline (Mesa Central)
CENOZOIC	Quarternary	Holocene		caliche, travertine, basalts, tuff fluvial deposits, chalk	Alluvion	Alluvion
		Pleistocene				
	Tertiary	Pliocene		rhyolithes	basalts	volcanics
		Miocene			rhyolithes / tuff	
		Oligocene				Ahuichila
		Eocene				
		Palaeocene				
MESOZOIC	Cretaceous	Upper	Maastrichtian	Cardenas	Tamasopo	Cardenas
			Campanian			
			Santonian			Caracol
			Coniacian			
			Turonian			Soyatal Indidura
		Middle	Cenomanian	El Doctor	El Abra Tamabra	Cuesta del Cura Taumalipas sup. Aurora
			Albian			
		Lower	Aptian	Guaxcamá	La Pena Guaxcamá	La Pena Otates
			Barremian		Taumalipas (inferior)	Cupido
			Hauterivian			Taumalipas inf.
			Valanginian			
			Berriasian			Taraises
	Jurassic	Upper	Titonian			La Casita-Trancas La Caja
			Kimmeridgian		La Casita	
			Oxfordian			Zuloaga
			Callovian			
		Middle	Bathonian		La Joya	La Joya
			Bajocian			
		Lower	Liasian			
	Triassic	Upper			Huizachal	Zacatecas, Nazas- Huizachal
		Middle				
		Lower				
PALAEOZOIC						

no outcrops known
not deposited (hiatus)

2.3. Hydrogeology

2.3.1. Surface water

Physiographically the 4.500 km^2 large basin is divided in 6 subbasins:

- in the northwest Cerritos-Villa Juárez subbasin (794 km^2) with the rivers Los Aguantos, El Sauz, La Caldera, El Palmito, San Pdero, La Mora, El Santo and El Brinco
- south of Cerritos-Villa Juárez the San Isidro subbasin (357 km^2) that is artifically drained to the rio Choy, other rivers are El Tigre, Choy, Camposanto, Nacimiento
- in the north San Bartolo subbasin (838 km^2) with the rivers Cien Tinajas, Sta. Teresa, Las Flores and La Cañada
- in the south San Ciro subbasin (272 km^2) subaquatically drained to rio verde or rio Santa Maria
- north of San Ciro the Rio Plazuela subbasin (550 km^2) that is drained to the rio Plazeula with the rivers Santa Rita, Los López, Nacimiento
- and the biggest subbasin, the Rioverde subbasin sensu stricto (1720 km^2) drained by the rio verde ("green river")

(SECRETARIA DE RECURSOS 1972)

The river "rio verde" rises 35 km east of San Luis at 2600 masl in a relatively flat area. The general flow direction is NW-SE parallel to the river Santa Maria that rises 14 km east-southeast of Ocampo/Guanajuato at 2500 masl and joins the rio verde east of the Rioverde basin. The rio verde confluents feed the main stream from the left riverside, only very few water is extracted for irrigation. From Villa Morelos at 1600 masl on the river turns to the southeast in a wide curve and crosses the first small mountains at San Nicolas Tolentino, small tributaries coming there from both sides (TACSA 1998). After the resurgence through these mountains the flow gauging station Nogal Obscuro records the entire water volume flowing from the "cuenca alta" (the high basin) to the actual Rioverde basin. The drained area of 2244 km^2 supplies approximately 115 Mio.m^3/year (SECRETARIA DE RECURSOS 1980), but Fig.13 and App.No.4 show that the amount normally appears as maximum in July and/or September depending on the rain period and mostly from November to April, in 1980, 1986 and 1987 even the entire year there is no flow measured at all.

The rio verde then crosses the southern part of the Rioverde basin more or less exactly from the northwest to the southeast not changing its course to the morphologically favored NW-SE orientated lineament in the south, but penetrates again through mountaineous area further to the east at 950 masl. At the entry to this zone the water volume is measured at the Vigas station. The drained area is 3964 km^2, the records mostly show summer peaks from the additional precipitation input during the rain period but in general the flow volumes are more balanced (Fig.13 and App.No.4) with an average volume of 299 Mio.m^3/year (SECRETARIA DE RECURSOS 1980).

This is owed to the fact that downstream the village la Reforma at an altitude of approximately 1020 masl, just about 15 km west of the town Rioverde the river flow is permanent - and not only periodical in rain seasons - due to the rise of the "manantial rio verde" (rio verde spring, La Taza, see Appendix - Mapping, well and spring description) with an average yield of 40 L/s. TACSA (1998) also mentions cutting of the basin´s aquifers crossing the river as an additional input. The amount of this drainage is calculated to be 16 Mio.m^3/year from the southern part (SECRETARIA DE AGRICULTURA, 1972) respectively 36.2 Mio.m^3/year from the entire basin (16.4 Mio.m^3/year from the Villa Juárez subbasin, 3.7 Mio.m^3/year from the central part near Pastora and 16.1 Mio.m^3/year from the southern part) (SECRETARIA DE AGRICULTURA, 1980). In the past the river yield was further increased in the basin due to discharge from irrigation channels coming from the spring Media Luna (see Appendix - Mapping, well and spring description) in the south. Water not used for irrigation (58 Mio.m^3, SECRETARIA DE RECURSOS 1972) was flowing to the river. Nowadays this irrigation channel has a siphon below the river and carries irrigation water further north, so no water is led to the river anymore.

From the basin´s outlet further to the east 10 km upstream of the confluence with the river Santa Maria the total volume of the rio verde is measured at Tanlacut station (Fig.13 and App.No.4) with approximately 239 Mio.m^3/year (SECRETARIA DE RECURSOS 1980).

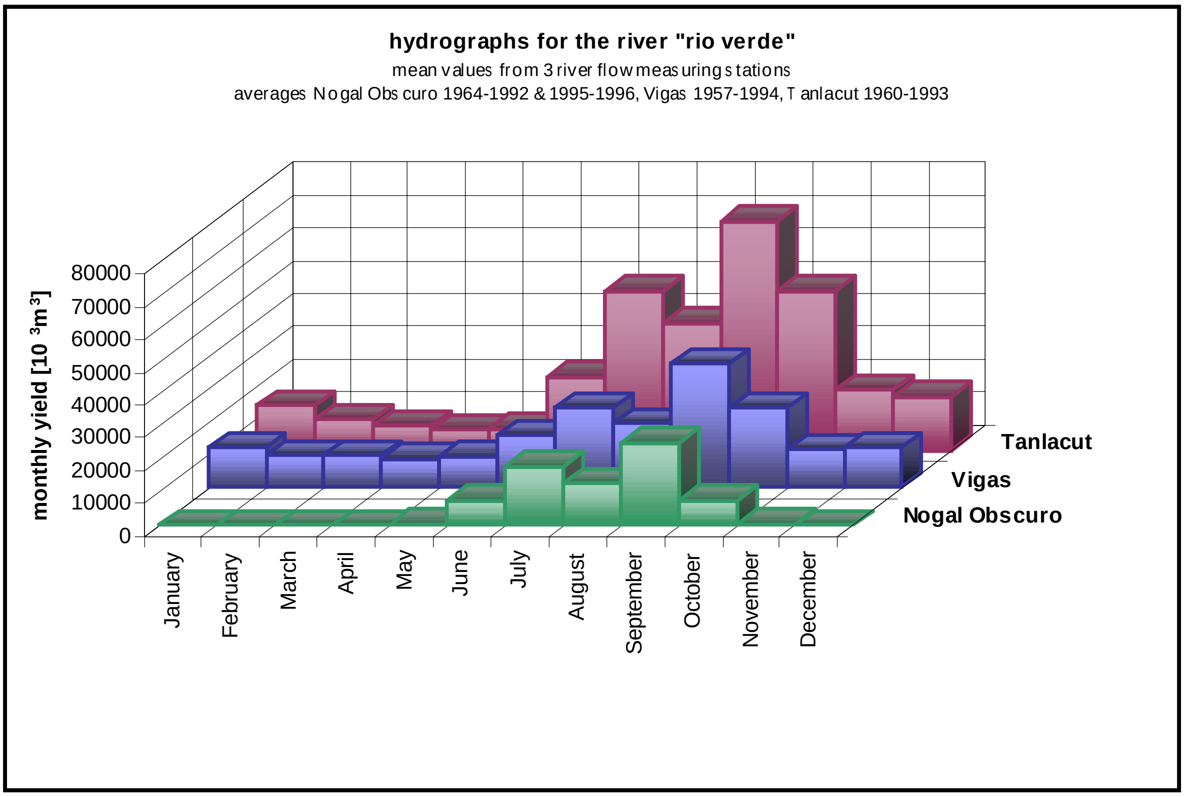


Fig. 13 Hydrographs for the river "rio verde" from 3 different river flow gauges

Downstream the confluence with the river Santa Maria the rio verde is named rio Tampaón, after the confluence with rio Gallinas rio Tamuín and after the confluence with rio Moctezuma in Las Adjuntas rio Pánuco, which flows into the Golf of Mexico with a general east to northeast flow direction. The total length of the rio verde from the spring to the confluence with rio Santa Maria is 186 km (SECRETARIA DE RECURSOS 1980). Average inclinations come to 3-5°, whereas the smaller seasonal rivers in the subbasins have inclinations of 8-13° (TACSA 1998).

A small river of some importance in the study area is the Nacimiento, rising from a spring in the basin´s southwestern part at 1350 masl with a yield of 35 L/s. The river has a permanent flow until the village

Arquitos where the yield is already decreased due to infiltration into El Doctor limestone outcropping 3 km upstream of the village. Near San Martin the Nacimiento totally disappears in Quarternary conglomerates contributing its water to the aquifer´s recharge. 28 minor springs especially east of the road Rioverde - San Ciro on the right riverside have only small yields not feeding any streams of even minor importance.

2.3.2. Groundwater

Two (sometimes three) main aquifers bordered by three aquicludes are reported. The deepest impermeable strata is the Lower Cretaceous Guaxcamá formation. The generally quite soluble gypsum sequence here acts as an aquiclude due to gravity compaction from the overlying rocks and the time it had for calcification. This aquiclude is overlain by the basin´s deepest aquifer in the Middle Cretaceous reef limestones of El Doctor formation. The rocks present secondary permeability due carstification. In the basin´s eastern part the aquifer´s piezometric level is quite low, however in the western and southern part it is so high that karst springs with high productivity (Media Luna 4.35 m^3/s, Anteojitos 0.25 m^3/s) occur at the surface (SECRETARIA DE RECURSOS 1972). The Upper Cretaceous Cárdenas formation with impermeable silt and clay layers confines the El Doctor aquifer to the top, partially also forming subterranean barriers for the lateral subaquatic flow.

The Tertiary rhyolithes are reported to be more or less impermeable (except for some open fractures) acting as lateral flow barriers in the subsurface or causing increased runoff at the surface. In the south of the basin permeable Tertiary basaltic lava permits the drainage of the phreatic and superficial water of the subbasin San Ciro and presents a local additional aquifer (SECRETARIA DE RECURSOS 1972).

The most widely distributed aquifer is the Quarternary unconfined porous aquifer build by coarse fluvial sediments. Other Quarternary formations like lacustrine sediments or hard calcificated Caliche form impermeable or at least reduced permeable layers or covers, especially on the left riverside of the rio verde.

The main recharge of the aquifers is supposed to result from precipitation in the Sierra at altitudes between 1500 masl and 2500 masl. Either this precipitation infiltrates to the permeable limestones and contributes to the recharge of the karst aquifer or temporarily runs off on impermeable rhyolithes down the valley sides infiltrating in the porous aquifer. Part of the recharge to the Quarternary aquifer may also come from direct precipitation infiltration inside the basin in areas where impermeable Caliche cover of clayey lacustrine sediments don´t exist. In areas with impermeable cover the precipitation gathers and forms surface lakes or lagoons that evaporate like the Laguna Seca east of San Bartolo basin (SECRETARIA DE RECURSOS 1972).

2.3.3. Human use and effects on surface and groundwater

2.3.3.1. Surface water

The previously described groundwater and surface water resources are heavily exploited for drinking and especially irrigation water use (Fig.14).

Fig. 14 Open irrigation on tomatoe plants NNW of Rioverde

The irrigated area was enlarged from 3,500 ha in 1972 (SECRETARIA DE RECURSOS 1972) to 6,000 ha in 1980 (SECRETARIA DE AGRICULTURA 1980) to 15,000 ha in 1998 (TACSA 1998).

The main surface water supplier is the karst spring Media Luna. Media Luna and Anteojitos 4 km further to the northeast are considered to be part of a larger regional system also including 3 major springs 38 km further N-NE, named "Los Peroles", and several minor springs east of the road Rioverde - San Ciro, probably fed by lateral flow from the major springs.

Media Luna has an average yield of 4.35 m^3/s. With the description of the Media Luna in Appendix - Mapping - well and spring description, a table is listed that shows monthly records from 1965-1999 with an absolute minimum of 2.867 m^3/s (August 1990), and a maximum of 6.6 m^3/s (April 1968). Fig.15 illustrates seasonal as well as longtime fluctuations.The seasonal fluctuations calculated as a monthly average from 34 monthly values (1965-1999) are low. Slight maxima occur in April and October, minima in January and September, but the differences between maxima and minima are less than 0.15 m^3/s. The longtime fluctuations are more distinct, maximum (1968) and minimum (1990) differ by 2.42 m^3/s. The average yield 1999 with 4.36 m^3/s equals almost the total average yield over 34 years (4.35 m^3/s).

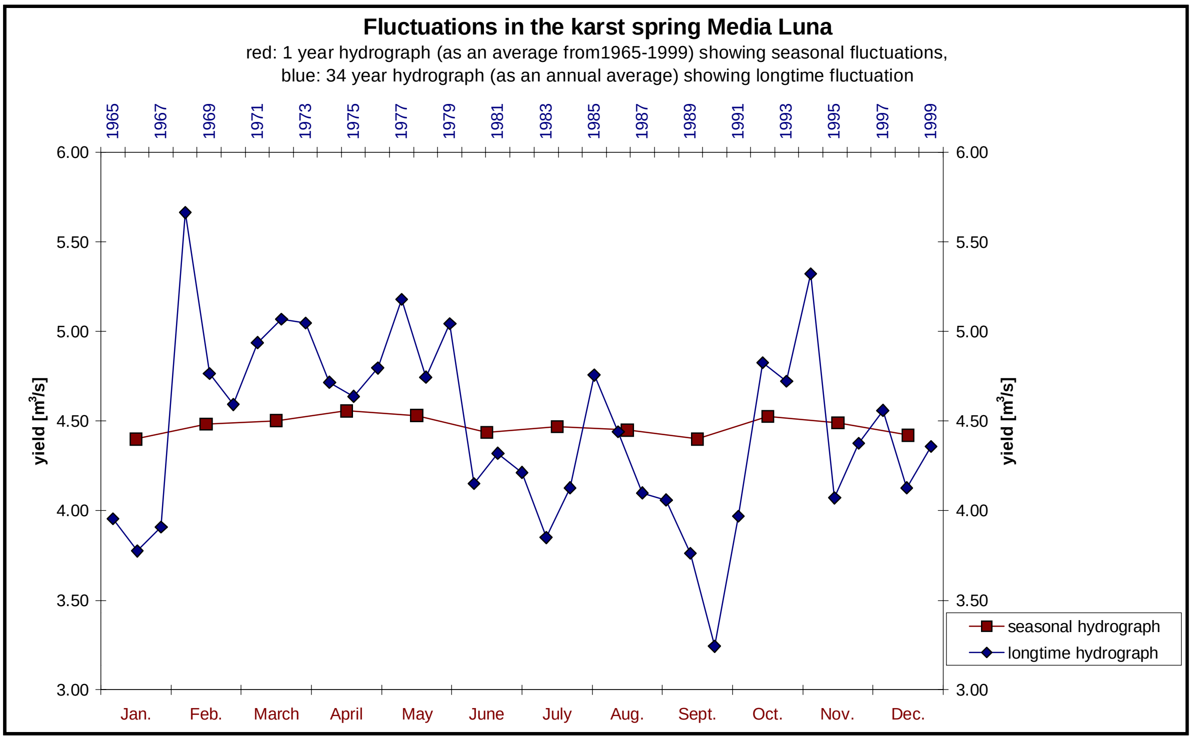


Fig. 15 Fluctuations in the karst spring Media Luna - seasonal (units on lower x-axis) and longtime hydrograph (units on upper x-axis)

Media Luna was first mentioned in 1617 with the construction of two aqueducts to the village of Rioverde, in 1732 an irrigation channel was build to irrigate the land of today´s Cd.Fernández for the growing of sugar cane. In 1917 the irrigation system was further enlarged due to the introduction of citrus fruits growing. 1977 the entire irrigation system was reconstructed in order to enlarge the irrigation area.

5 main channels were dug (channel "Fernández" and "Rioverde" conducting water to the north, channel "San José" with 3 subchannels in Aguacates, two ending in Bordo Blanco, one continuing to Plazuela, joined with smaller streams and water from some small springs this water continues to the east, finally flowing into the rio verde between Santa Isabel and Paso Real) and the channels "Potrero de Palos" and "Capulin" ending east of Palomas in Capulín without flowing to the rio verde).

Later the two channels "Fernández" and "Rioverde" were interconnected to one main channel "Principal Media Luna" measuring 37.7 km (Fig.17). The entire distribution net covers 89.6 km, the drainage net 82.8 km (CNA 1991). Today practically all the water from the Media Luna is used for irrigation (4.35 m^3/s).

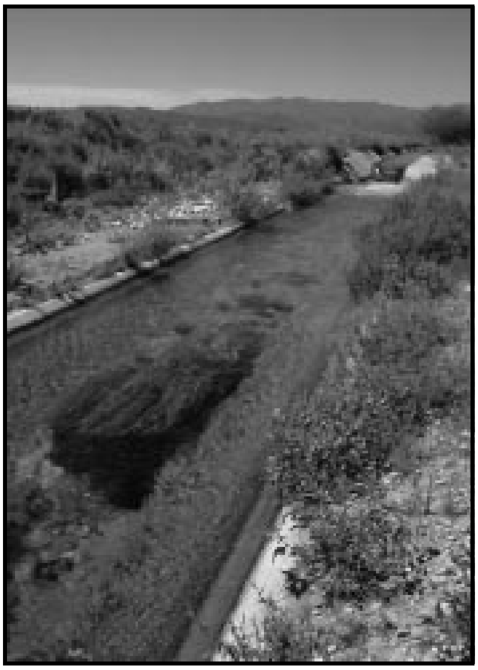


Fig. 16 Irrigation channel from the Media Luna to the east

Fig. 17 Main irrigation channel from the Media Luna to the north (left: new one, right: old one)

To increase the irrigation rate further a pumping plant on a floating base in the Media Luna was planed to irrigate higher areas (4 groups of vertical pumps in 5, 3 and 2 m with a proposed yield of 8.4, 9 and 10.4 m^3/s) (ALVARADO PEDRAZA 1981), but this project is abandoned today and only some ruins of the old pipes remained (Fig.18).

Fig. 18 Remnants of the pipes and the storage basin for a planed irrigation project at the Media Luna

Another ambitious project was the construction of a storage basin on the right river side of the rio verde south of Miguel Hidalgo in the southeastern part of the valley (Acequia Salada) from where water ought to be pumped with 4 big pumps uphill and then conducted by gravity to the dry area of San Ciro to irrigate new agriculture area. It was also planed to capture additional water from the springs Palma Larga, Charco Azul, Agua Sonadora and El Sabinito. The main channel with a length of 15.7 km was constructed, also the distribution net of 39.7 km and the drainage net of 1.7 km (CNA 1991). But when the project started too much water was taken from the river and downstream the rio verde went dry. The project was skipped; today the place is abandoned, the electricity equipment and one pump already stolen (Fig.19).

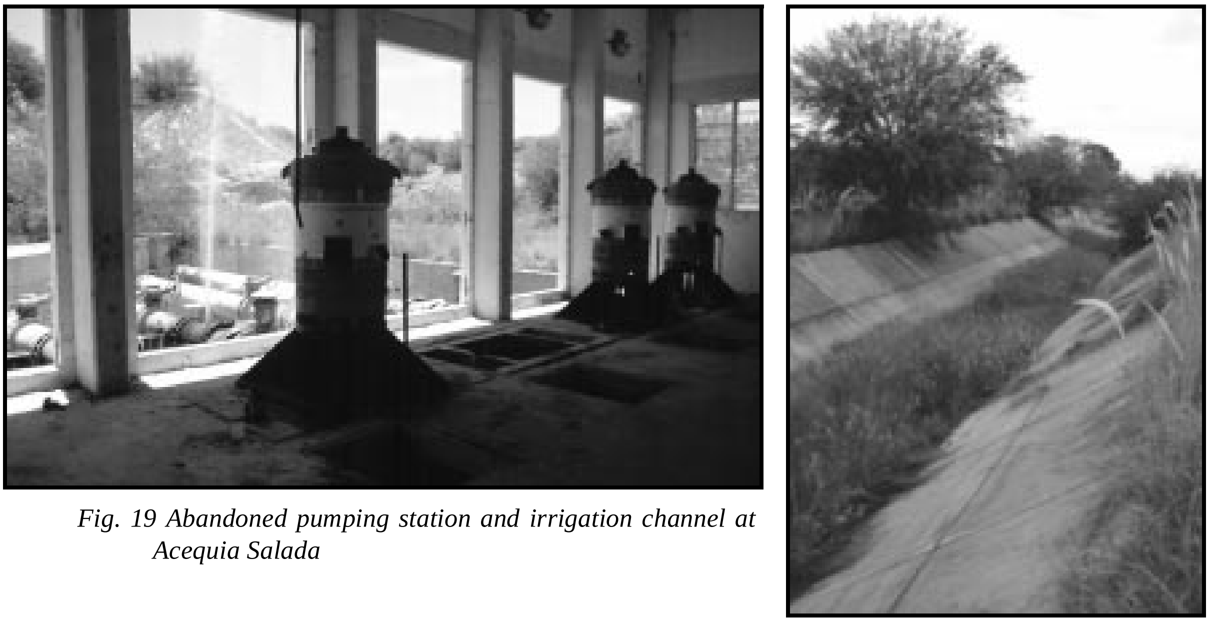


Fig. 19 Abandoned pumping station and irrigation channel at Acequia Salada

The main purpose of the irrigation channels was of course to provide irrigation water for agriculture use. However as a side effect the canalization and the drainage system lowered the phreatic head that was very near to the surface and by this the cultivation of former "useless" wetlands was possible (Fig.20).

Fig. 20 Former lagoon, today cultivated land - El Jabali

1970 13 water bodies like lagoons or lakes were described, today only the artificial lake San Diego (Fig.21) exists. 5 wetlands areas were reported, nowadays only 3 still exist (Fig.22) however endangered by drying out in the near future (SECRETARIA DE AGRICULTURA 1972).

Fig. 21 Artificial lake - dam San Diego


Fig. 22 A wetland area still existing - Tlacomates

In 1994 a study was performed to investigate the impact of irrigation, canalization and drainage on the springs and wetlands (SECRETARIA DE ECOLOGIA 1998). The study shows that especially the large wetlands north of Media Luna to the village San Marcos and around Anteojitos formed by water following the natural discharge direction were drastically reduced. The formation of travertine decreased in the whole area around the springs due to the canalization of the calcium rich spring water. In the spring Anteojitos consisting of two craters the natural flow direction from the major to the minor crater was changed by the construction of an irrigation channel. The present flow direction from the minor to the major crater and an increase in flow velocity engraved the erosion on the borders of the water body already iniciated by man made impact. Finally since the lateral infiltration from the major springs was reduced the yield of the springs east of the road Rioverde - San Ciro seems to have decreased, especially in the spring "La Palma Larga".

Consequently SECRETARIA DE ECOLOGIA (1998) proposed a natural protection zone of 4.9 km NE-SW and 2.7 km N-S around the two springs containing 5 subzones with different degrees of protection:

- **inner zone:** more or less intact areas, any use prohibited except for research, refuges for endangered fauna (fish: Cichlasoma labridens, bartoni, cyanoguttatum, steindachneri, Cualac tesellatus, Ataeniobius toweri, Dionda mandibularis, dichroma, erymyzonops; birds: Cardinalis cardinalis, Ceryle torquata, Branta canadensis, Dendrocygna autumnalis, Aquila crysaetos; mammals: Lynx rufus, Odocoileus virginianus) and flora; containing part of Media Luna, Isla del Centro, eastern channel and both borders, the small spring of Anteojitos
- **regeneration areas:** areas with severe man made impact, necessary to restore (limitation of visitors (at present: 2,000-4,000 visitors per day), prohibition for any urban or rural enlargement, reforestration, planting the original vegetation, enlarging the remaining wetlands)
- **buffer zones:** between the protection zones sensu stricto and the zones of intensive use, only restricted use
- **zones of extensive use:** minor man made impact, public use not restricted, but encouragement to "close to nature" use ("touristic corridors")
- **zones of intensive use:** agriculture and fishing areas with a high degree of man made impact, only interventions: controlling the impacts and testing more efficient agricultural methods with less use of agrochemicals

This proposal seems to have been realized and the SECRETARIA DE ECOLOGIA was still working on further characterization of these and other springs and their man made impact in 1999.

2.3.3.2. Groundwater

Another problem far less conscious to the public presents the intensive exploitation of *ground*water. In the entire basin there are more than 1000 deep and shallow wells, only around Rioverde approximately 600 wells and in the study area an estimated 300 wells extracting water from the Quarternary and the Cretaceous aquifer. An idea of the extracted volumes is hard to obtain.

SECRETARIA DE AGRICULTURA (1980) presents an estimation of a total extracted volume of 74 Mio.m^3/year from springs, shallow and deep wells classified according to different consumers (App.No.5b), but one should not rely too much on these numbers. App.No.5c shows an estimation of the amount of water that is extracted from wells for Rioverde´s drinking water supply in 1999 with the normal 24 hours-a-day operation not taken into consideration time out of order for repairs or cleaning. These 7 Mio. m^3/year are hard to classify, the main share is for "domestic use", but it is also used for gardening and some agricultural irrigation. Some industries may also get their industrial water from the official water supply, others are known to have separate wells. For the numerous smaller irrigation or private household wells with irregular operation times, unknown pumping rates, water loss in pipes, etc. it is almost impossible to estimate anything, but the numbers from SECRETARIA DE AGRICULTURA (1980) show that especially these wells contribute the major part to the extracted water volume.

The consequent development of the groundwater tables has been discussed quite controversial. SECRETARIA DE AGRICULTURA (1980) presents a map showing the development of the groundwater table from 1972 to 1980. While significant drawdown predominates in the El Refugio (-4 to -8 m) and Pastora area (-1 to -6m) there are also areas of recharge east of Rioverde (+1 to +8 m), north of the highway to San Luis(+1 m) and in the north around Joya del Cardon (+1 to +3 m). PROYESCO (1981, cited in TACSA 1998) calculates a hydraulic balance of $42.7*10^6$ m^3 recharge with an extraction of $74*10^6$ m^3 and points out a heavy overexploitation. A study for CNA (1986) results in a map with the development of groundwater tables from 1980-1986 and also illustrates variable heavy drawdown (-2 to -3 m in Pastora area, -1 to -3 m in Las Palmas (NE of Rioverde), -1 to -2 m in Ildefonso Turrubiates (E of Rioverde), -3 to -6 m in El Refugio, -5 to -6 m El Jabali, -2 to -3 m north of the highway to San Luis). In contrary to this in TACSA (1998) another study is mentioned also conducted for CNA in 1986/87 according to which the drawdown in El Refugio is only 2 m, north of the highway to San Luis there is even an upconing of 2 m, so they conclude the aquifer being in equilibrium. HOFMANN et al. 1993 (cited in HOFMANN 1994) calculate an extraction of 150 L/s from the wells for drinking water supply, estimate another 200 L/s from private wells for irrigation water and model with this a drawdown of 1 m/year in the El Refugio area.

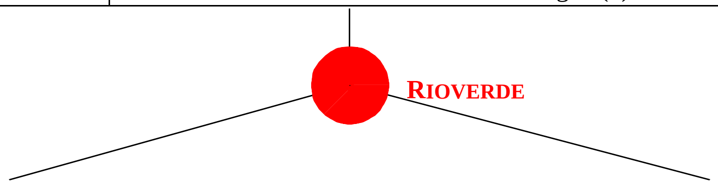
2.4. Hydrochemistry

2.4.1. Reports on the basin´s hydrochemistry

The hydrogeochemistry of the aquifers reflects the influence of the geological surroundings. In detail the results of the different projects (e.g. SECRETARIA DE RECURSOS HIDRAULICOS 1972, ALAVARDO 1973, SECRETARIA DE RECURSOS HIDRAULICOS 1980, ALVARADO 1981, COMISION FEDERAL DE ELECTRICIDAD 1984, MONTANEZ 1992, de la PENA 1994, HOFMANN 1994, SECRETARIA DE ECOLOGIA 1998) differ but there is an obvious general trend.

Tab. 3 General hydrochemistry in the Rioverde area (results from: 1 = Secretaria de Recursos Hidraulicos 1980; 2 = de la PENA 1994; 3 = Comision Federal de Elecricidad 198; 4 = Montanez 1992; 5 = several unpublished analysis from SASAR)

North of Rioverde	
TDS	1500-2300 mg/L (Pastora) (1) 3000-4000 mg/L (Muralla) (1) 192-5120 mg/L (4)
conductivity	600-11200 µS/cm (3) 375-8000 µS/cm (4)
SO_4	500-800 mg/L (Pastora) (1) 800-900 mg/L (Muralla) (1) 20-10725 mg/L (3) 28-1056 mg/L (4)
Ca	400-600 mg/L (Pastora) (1) 100-300 mg/L (Muralla) (1) 60-761 mg/L (3) 40-721 mg/L (4)
Cl	500 mg/L (Pastora) (1) 17-1019 mg/L (3) 12-599 mg/L (4)
Na	1-10 mg/L (1) 0-7.35 mg/L (3) 0.1-22 mg/L (4)



Southwest (El Refugio)	
TDS	250-500 mg/L (1) 238-1024 mg/L (2)
SO_4	40-70 mg/L (1) 4-235 mg/L (2) 15-331 mg/L (5)
Ca	50-70 mg/L (1) 35-115 mg/L (2) 17-116 mg/L (5)
Cl	40-170 mg/L (1) 3.5-7.0 mg/L (2) 5-99 mg/L (5)
Na	2-3 mg/L (1) 2-26 mg/L (2) 1.15-33 mg/L (5)

Southeast (east of the road Rioverde - San Ciro)	
TDS	1000-2000 mg/L (1) 4150 mg/L (La Ilusion) (2)
SO_4	100-400 mg/L (1) 3210 mg/L (La Ilusion) (2)
Ca	200-500 mg/L (1) 536 mg/L (La Ilusion) (2)
Cl	100-400 mg/L (1) 180 mg/L (La Ilusion) (2)
Na	10-20 mg/L (1) 180 mg/L (La Ilusion) (2)

SW of Rioverde in the El Refugio area most groundwater samples show low mineralization, low conductivity and temperatures between 25-29°C. The waters are characterized by several of the above mentioned studies as calcium-hydrogencarbonate type. North and southeast of Rioverde there is a steep increase to high conductivity and high mineralization and a slight decrease in temperature to 24-27 °C. The predominant water type there is classified as calcium-sulfate type. The high sulfate and calcium and increased chloride and sodium concentrations north and east of Rioverde are interpreted to result from water circulating through evaporitic layers, especially gypsum layers. Increased strontium concentrations (0.08-8.32 mg/L) may also result from evaporite leaching (de la PENA 1994). Hydrothermal influences in these areas may be represented by elevated fluoride (0.05-2.7 mg/L), phosphate (0.06-0.80 mg/L) and high arsenic concentrations (however the values of 0.7-3.9 mg/L As cited in de la PENA 1994 and HOFMANN 1994 are questionable, App.No.35a). To compare the above mentioned concentrations with average groundwater concentrations see App.No.36.

The few trace element analysis that have been conducted for selected elements (de la PENA 1994, several unpublishes analysis from SASAR) were contradictory and mostly below the detection limits of the method applied.

The karst springs Media Luna and Anteojitos (ALVARADO 1981, SECRETARIA DE ECOLOGIA 1998) as well as the Manantial rio verde (de la PENA 1994) show their own, very similar chemistry with high temperatures around 30°C, high TDS (900-1500 mg/L) and increased sulfate (-880 mg/L) and calcium (-300 mg/L) concentrations.

2.4.2. Pesticides

In the area of intensive agricultural use around El Refugio many pesticides have widespread application. The most important ones were named to be Folidol M-50, Parathion Metilico 50, Parathion 75%, Lorsban 480E, Sevin 80, Karate, Ambush, Decis 2.5, Tamaron, Lucation 1000, Agrimec as well as the insecticides Lindane, Lannate, Thiodan, Tamaron 600, Arrivo, Gusation M-20 and 35 PH, Malation 500 and 1000 and the herbicides Poast, Fusiliade, Faena, Esteron 47, Gramoxone, Hierbamina, Hierbester. Moreover the use of DDT, at least in the past, was suspected.

Fig. 23 Pesticides application on mais plants

The general characteristics of pesticides that were detected in the wells sampled during this thesis in 1999 are described in the following.

The organophosphate *parathion*, main part of Folidol M-50, Parathion Metilico 50 and Parathion 75%, is classified in the EPA as highly toxic, most of the available formulations may be classified as restricted use pesticides (RUPs) and may be purchased and used only by certified applicators. Parathion is sorbed rapidly into the bloodstream but does not accumulate in the body and is almost completely excreted by the kidneys as phenolic metabolites within about 24 hours. In soil and groundwater environment it also shows low persistence with reported half-live times of 1-30 days.

The use of the highly effective organochlorate-insecticides *aldrin* ($C_{12}H_8Cl_6$) and *dieldrin* ($C_{12}H_8Cl_6O$) has been severly restricted or banned in many parts of the world in the early 1970s. In soil aldrin is removed by evaporation or oxidation to dieldrin which disappears rather slowly with reported half-life times of about 5 years. Concentrations in aquatic environments are reported to be less than 10 ng/L, since the leaching from soils is low. Both compounds are highly toxic for the human central nervous sytem and the liver (WHO 1996).

Heptachlor ($C_{10}H_5Cl_7$), applied for soil and seed treatment (mais), is moderately persistent in soil (up to 2 years) and may undergo significant photolysis, volatilization and oxidation, especially to *heptachlorepoxide* ($C_{10}H_5Cl_7O$) which is very resistant to further chemical or biological changes. For the removal of heptachlorepoxide from aquatic systems only volatilization is reported to play a major role. Heptachlor has certain negative effects on the central nervous system, but does not appear to be carcinogenic to humans (WHO 1996).

An effective insecticides on fruits and vegetable crops is *lindane* ($C_6H_6Cl_6$, γ-HCH). It´s degradation in soil strongly depends on the oxygen supply with reported half-life times of 88 to 1146 days under aerobic conditions and 12-174 days under anaerobic conditions. Hexenes, Benzenes and in case of aerobic degradation phenoles are the degradation products. Leaching of lindane to groundwater is stated to "occur rarely", reported levels in groundwater range from 3 to 163 ng/L. Effects on humans are neurophysiological and neuropsychological disorders and gastrointestinal disturbances, gentoxicity is not supposed (WHO 1996).

The organochlorate *DDT* (**D**ichloro**d**iphenyl**t**richlorethane, $C_{14}H_9Cl_5$) was first introduced in 1939 as an insecticide mainly on citrus fruits or cotton especially to control malaria, typhus and other insect-transmitted diseases. 1972 the USA outlawed the use of DDT by American farmers on crops grown in the country, but there were no such regulations for import or export products. Thus in many other countries the application of DDT continued even when the EPA proposed a total ban over the substance in 1984. DDT is especially harmful due to its persistence in the environment and the potential of accumulation along the food chain. It sorbs in direct proportion to the dietary exposure especially in fatty tissues due to high lipid and low water solubility (1µg/L). The t(1/2) for clearance takes about 10-20 years, it is higher for 4,4-DDT than for 2,4-DDT. DDT is classified as "probable human carinogen". Together with DDT *DDE* ($C_{14}H_8Cl_4$) and small amounts of *DDD* may be detected as its breakdown products, also considered to be "probable human carinogen" (WHO 1996).

No investigations on pesticides were ever conducted in the Rioverde basin until 1999.

2.4.3. Arsenic

The reasons for focusing on arsenic in the basin of Rioverde were the two reports from HOFMANN (1994) and DE LA PENA GAMEZ (1994) already mentioned above publishing the same data for 9 wells and 3 springs with arsenic contents of 0.7 up to 5.9 mg/L. These concentrations exceeding about 100 times the Mexican drinking water level of 0.05 mg/L would have presented a real danger for agriculture and population especially since no water treatment exists at all.

Besides the idea of high arsenic contents in the Rioverde basin seemed quite realistic since the geological situation is similar to the one in Zimapan, Hidalgo where As concentrations of up to 1 mg/L have been reported in the groundwater (chapter 2.4.3.6). High arsenic contents were already reported from the Las Cuevas fluorite mines (RUIZ et al. 1989) about 80 km west of Rioverde and the fluorite district El Realito and El Refugio, about 45 km southwest of Rioverde was said to have had serious problems with high arsenic contents during their active mining phase.

2.4.3.1. Arsenic Chemistry

2.4.3.1.1 General chemistry

Arsenic (As) is a semi metal (metalloid) or transition element belonging to the 5th group of the periodic system of elements, atomic number 33, atomic mass 74.9216. The elemental stabile arsenic is a gray, rhomboedric cristalline material with a density of 5.727, a hardness of 3-4 MOHS, a melting point of 817°C (at 28 atm) and a sublimation point of 633°C. Heated beyond this sublimation point yellow vapor forms, which turns to yellow, waxen like, cubic arsenic when cooled rapidly. This yellow arsenic is quite similar to white Phosphorous in solubility and fugacity. Yellow arsenic as well as all the other amorphous arsenic modifications turns very easily to the metallic gray form (MORTIMER 1987).

Arsenic is one of the few anisotropic elements with only one stabile isotope ^{75}As. Besides artificial isotopes from ^{66}As to ^{74}As and ^{76}As to ^{87}As exist with life times of 0.9s to 80.3 days but none of them has any relevance as environmental isotope (MERKEL & SPERLING 1998).

245 arsenic bearing minerals are known in nature, 4 modifications of elementary arsenic, 27 arsenides (like Nickeline, Löllingite, Safflorite, Rammelsbergit), 13 sulfides (Arsenopyrite, Realgar, Enargite, Orpiment), 65 sulfohalides, 2 oxides, 11 arsenites, 116 arsenates (Mimetasite, Erythrine, Annabergit) and 7 silicates (RÜDE 1996).

Arsenic forms no single cations in solution, but reacts readily to form insoluble complexes with metals or covalent bonds with carbon, hydrogen and oxygen. The most common arsenic acids are H_3AsO_4, $H_2AsO_4^-$ and $HAsO_4^{2-}$ with the corresponding salt arsenate ($As(V)O_4^{3-}$) as well as the weak arseneous acid H_3AsO_3 with the corresponding salt arsenite ($As(III)O_3^{3-}$) and in reducing environments $HAsO_2$. Fig.24 illustrates the pH dependent dissociation diagram for H_3AsO_4 and H_3AsO_3. Considering that the average groundwaters have pH values from around 4 to 9, the arsenic acid will occur as dihydrogen and hydrogen arsenate while the arseneous acid will stay undissociated. Extremely acidic mining water or waters in highly alcaline ultramafic soils for example may show other species.

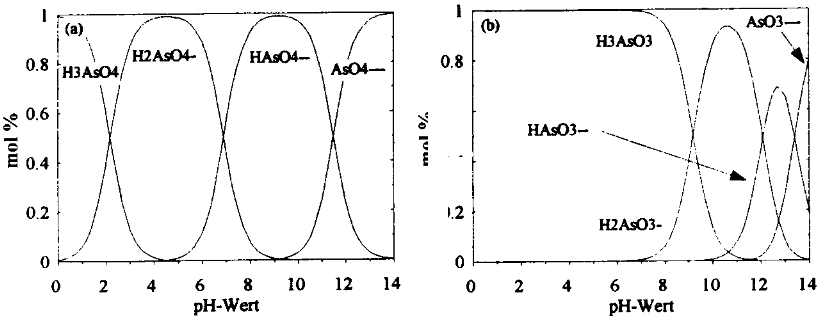


Fig. 24 pH dependent dissociation diagram for H_3AsO_4 and H_3AsO_3 (RÜDE 1996)

Arsenic Hydrogen (Arsine, AsH_3) with arsenic in its valency state -III is known as a colorless, flammable and unpleasant smelling and extremely toxic gas especially dangerous due to the fact that it is 2.7 times heavier than air. Arsenic halides like $AsCl_3$, a colorless, very toxic, oily fluid, and the also colorless and very toxic fluid AsF_3 are known but not found in nature because they are easily hydrolyzed (LANDNER 1989).

Organic arsenic compounds may be stable under a variety of environmental conditions of pH and EH. The most common of those are methanearsonic acid (= Monomethyl Arsonic Acid = MMAA = $CH_3As(V)O(OH)_2$) and dimethylarsinic acid (= Cacodylic acid = DMAA = $(CH_3)_2As(V)OOH$). While MMAA is strongly sorbed like arsenate, DMAA rarely is sorbed at all (HOLM et al. 1979). Fig.25 shows the pH dependent dissociation of MMAA and DMAA. Di- and trimethylarsines are a natural product of biological activity and may form the methylarsenic acids with water or soluble salts with alkali metals. Besides five different arsenosugars formed by algaes exist. They are unstable in strong alkaline or acidic solutions and supposed to be the key intermediate in the interconversion between arsenolipids and water-soluble species of arsenic (LANDNER 1989).

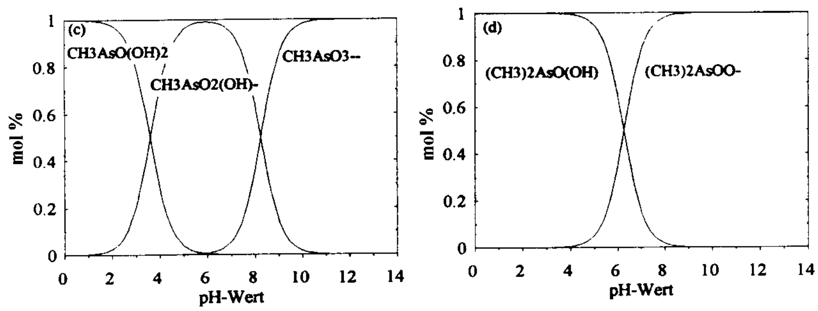


Fig. 25 pH dependent dissociation diagram for MMAA and DMAA (RÜDE 1996)

Especially due to the great variety of organic compounds the synthesis of at least 32.000 arsenic compounds is possible in the laboratory (NRIAGU 1994 II). Fig.26 shows several forms of naturally occurring arsenic, reaction paths for transformations and the conditions necessary for these reactions to run. Chained up is a metabolic cycle´s scheme of arsenic transformations in aquatic ecosystems. This arsenic cycle may be similar to the phosphorous cycle, but the regeneration times are much slower (in the order of several months) (NRIAGU 1994 II).

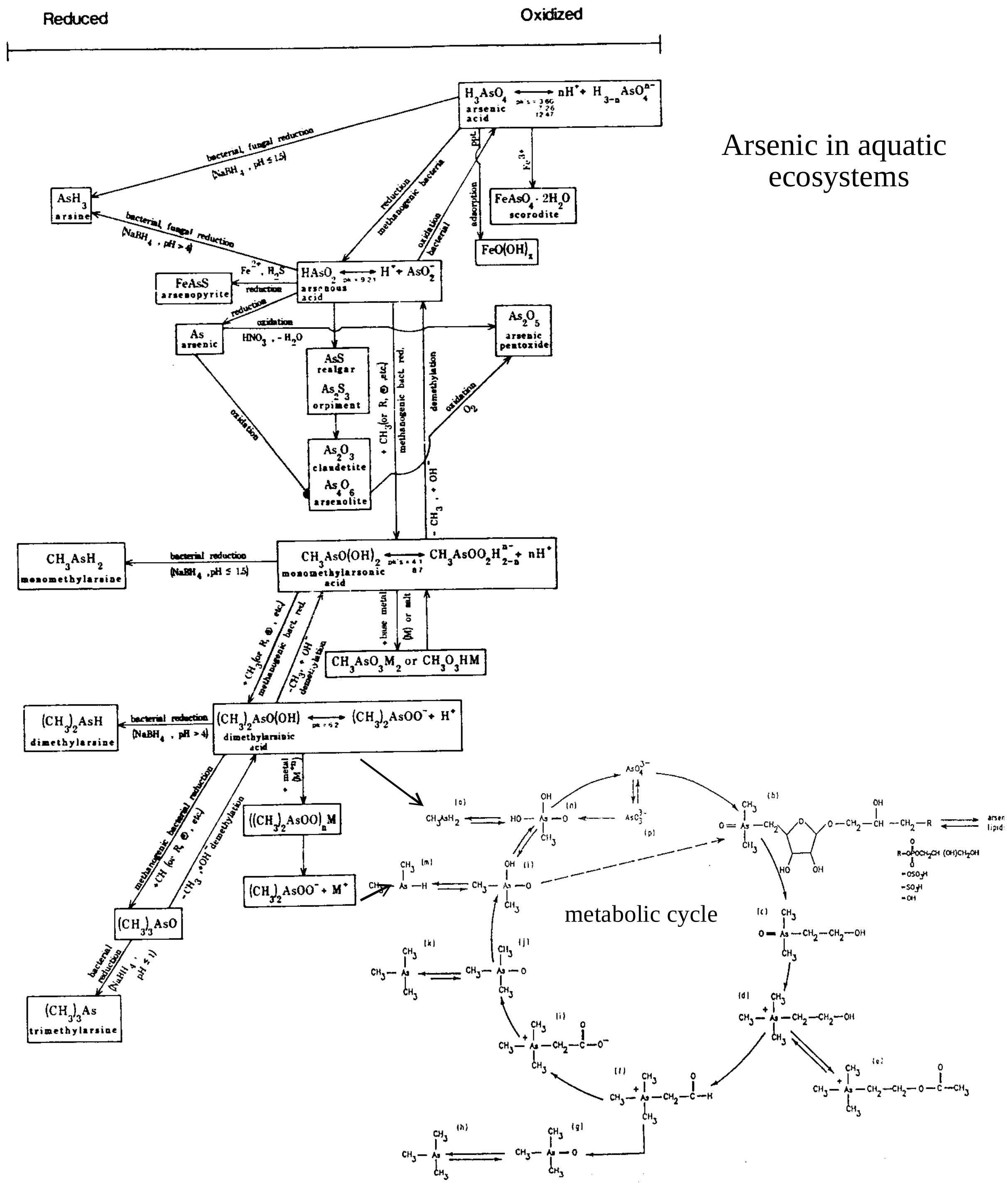


Fig. 26 Arsenic in aquatic ecosystems [combination of a metabolic cycle (LANDNER 1989) and a scheme of other natural occuring compounds with their reactions paths (WELCH et al. 1988)]

2.4.3.1.2 Sorption and Mobility

The two occurring valency states of arsenic, As (V) and As (III), are decisive for the behavior in aquatic systems. In Fig.27 the different arsenic species in correlation to pH and pe are presented.

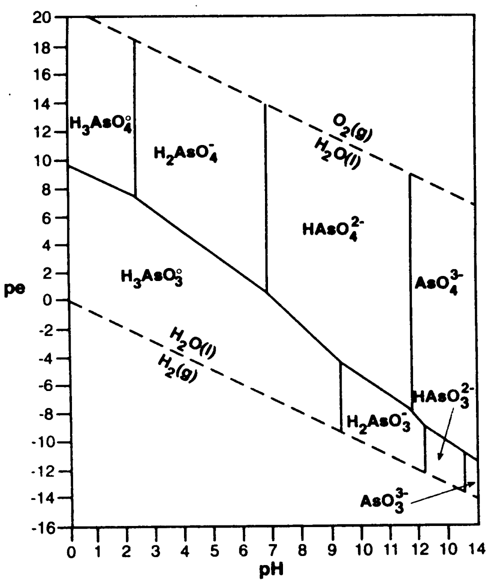


Fig. 27 Speciation diagram for As(III) and As(V) (DEUTSCH 1997)

While As (V) is sorbed on iron, manganese and aluminum oxides or hydroxides as well as on clay minerals and organic matter and therefore almost immobile, As (III) is about 4 to 10 times more soluble and mobile at least in the presence of the above mentioned oxides. The reason for this can be seen from the dissociation diagrams in Fig.24. Within the average pH range of groundwaters from 4 to 9 As(V) will occur as dihydrogen, being subject to ionic exchanges and sorption whereas As (III) will stay undissociated as neutral complex without immobilization mechanisms. The general tendency from strong to only weak or almost no sorption is $As(V)O_4^{3-}$ > MMAA > $As(III)O_3^{3-}$ > DMAA (HOLM et al. 1979). In competition with phosphorous for the same binding sites any arsenic compound´s sorption strength is higher than that of phosphorous (LANDNER 1989).

Column elution tests show that the As(III)/As(V) sorption strength is pH dependent (Fig.28). In reducing environment (pH 5.7) As (III) is detected 5-6 times sooner than As (V) and the amount of As (III) eluted is 8 times larger than that of As (V) due to the retention of As (V) by ferric oxides. At neutral pH the relative amounts unchanged, As (V) moves through column much more rapidly than before but is still retarded with respect to As (III). In oxidizing environment (pH 8.3) the As (V) mobility is accelerated, both species appear in the effluent after less than one column volume is displaced, both species are eluted almost quantitatively (100% As (III), 80% As (V)) (GULENS et al. 1979).

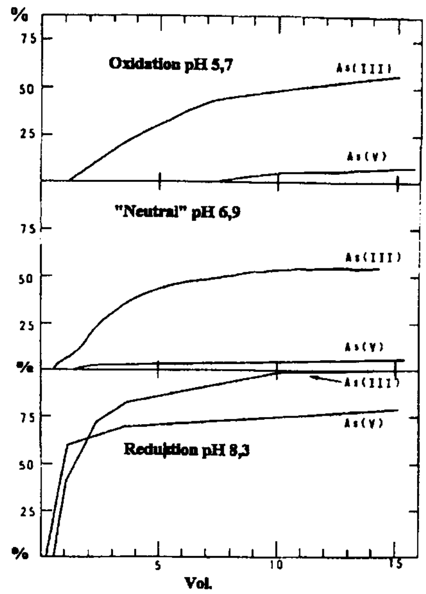


Fig. 28 Column elution tests showing the pH dependent sorption strength of As(III) and As(V) (MERKEL & SPERLING 1999)

The maximum sorption on iron-aluminum oxides is at pH 7 for As(III) and pH 4 for As(V), on organic matter pH 5.5 for As (V). Generally organic matter sorbs about 20% less As(III) than As(V) (NEUHAUS 1994). For As(V) RÜDE (1996) reports 100-120 mmol As(V)/kg sorbed at pH<5. The clay mineral Kaolinite is able to sorb about 0.5 mmol/kg at pH 5-8 due to ligand exchange with the aluminum octaeder´s OH groups. Manganese oxides show relatively high sorption capacity for arsenic, for example 10 mmol/kg on Pyrolusite and up to 400 mmol/kg on Cryptomelane, but due to the fact that Manganese concentrations in the soil are mostly low, this effect is not decisive (RÜDE 1996).

Fig.29 illustrates that the 100% As(V) sorption on hydrous ferric oxide is very stable over a wide pH range compared to Se(V), Cr and Se(III). Due to the fact that As(III) is fully protonated as H_3AsO_3 its sorption curve shows a different behavior with the maximum sorption at pH 7 (DREVER 1997).

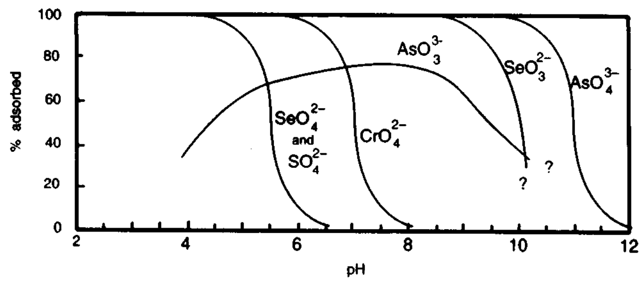


Fig. 29 Different sorption behavior of Se(V), Cr, Se(III), As(III) and As(V) (DREVER 1997)

Contrary to all this MANNING et al. (1998) carried out some studies suggesting that at neutral and alkaline pH As(III) actually has a higher affinity for iron(hydr)oxides than As(V) (Fig.30) probably related to differences in both´s surface complex structure.

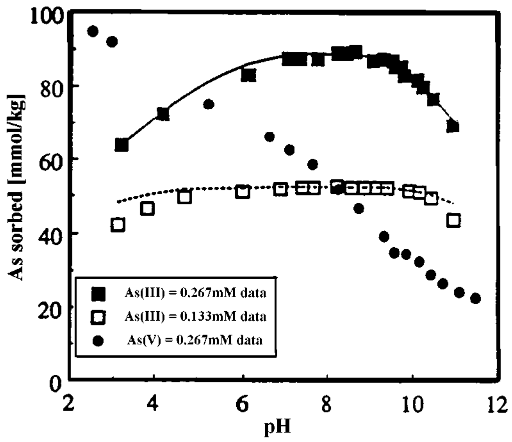


Fig. 30 Sorption of As(III) and As(V) depending on pH (according to MANNING et al. 1998)

Arsenic can also be bound through precipitations with Ca, Ba, S, Fe and Al, but these precipitations are slow in nucleating and show slow growth rates, so adsorption is the more important factor (HOLM et al. 1979). The most significant uptake in aquatic biota is the uptake of arsenate in algae and transformation to arsenite, methylated arsenic acids, arsenosugars and arsenolipids.

With all these sorptions mechanisms sediments are the main sink for arsenic input in aquatic ecosystems. NRIAGU (1994 II) even states that the sorption of arsenic on hydrous iron oxides is rather an incorporation into the sediments at the time of hydrous oxide formation than a real sorption onto existing surfaces.

Arsenic remobilisation from sediments can occur in different ways. Gaseous arsenic compounds can be removed as dissolved gas or inside other gas bubbles, like CH_4 (HOLM et al. 1979). Soluble species can reenter the arsenic cycle by changes in the redox conditions either through abiotic chemical processes or through microbially catalyzed actions. Arsenate reducing microorganisms like MIT 13, SES-3, OREX-4 and Chrysiogenes arsenatis (AHMANN et al. 1997) as well as several bacterias like DIRB (dissimilatory iron-reducing bacteria) and SRB (sulfate-reducing bacteria) (HARRINGTON et al. 1998), algaes and fungal species transform the insoluble As(V) to the mobile As(III) by producing hydrogen sulfide.

Once released as As(III) arsenic accumulates in the hypolimnion of the aquatic system and depending on seasonal changes can move to overlying water with seasonal turnovers when water from the hypolimnion is mixed with epilimnetic water leading to an increase in arsenic concentration on the surface of 10-20% (NRIAGU 1994 II).

RÜDE (1996) also claims that water soluble fulvic acids can cause arsenic mobilisation due to competition on anionic sorption sites. This process should gain importance with fulvic acid concentrations of more than 10 mg/L and with high pH values, probably accelerated because of OH- ions also competing for the same sorption sites. Besides RÜDE (1996) presents competition with phosphorous as a possible remobilisation source, but this is in contrast with LANDNER (1989) stating all arsenic compounds having higher sorption strength than phosphorous compounds.

The average residence time for arsenic in the aquatic system of oceans is estimated to be 60 000 years, in freshwater lakes 45 years (NRIAGU 1994 II). EMSLEY (1992) gives 90 000 years as residence time in seawater.

In soils another important remobilisation source is simply volatilization. According to THOMAS & RHUE (1997) as much as 35% of the arsenic species may be mobilized by volatilization as arsine, dimethylarsine and trimethylarsine.

2.4.3.2. Origin of increased arsenic concentrations

Increased arsenic concentrations are a worldwide problem. The sources are various and either man made or natural.

With 1.8 mg/kg in the earth´s crust arsenic is the 51. element in frequency (GREENWOOD & EARNSHAW 1990). Tab.4 lists the natural occurrence of arsenic in different compartments. Normally background concentrations are 0.2-15 mg/kg in lithosphere, less than 15 mg/kg in soil, 0.005 to 0.1 mg/m^3 in atmosphere and <10 mg/L in water (NRIAGU 1994 II). However Tab.4 illustrates that in certain geological surroundings like terrestric or marine semiarid-arid basins with an interbedding of evaporite sediments and mud layers, metal deposits especially iron ores, organic enrichments, metamorphic displacement deposits near volcanic eruption zones or hot springs and alteration zones due to thermal heating, even naturally the arsenic contents may be increased.

Tab. 4 Natural occurrence of arsenic in different compartments

lithosphere	**mg/kg**	**literature**
ultrabasites	0.3 - 16	RÜDE 1996
basalts, gabbros	0.06 - 113 (∅ 2.0)	RÜDE 1996
andesites, dacites	0.5 - 5.8 (∅ 2.0)	RÜDE 1996
granites	0.2 – 13.8 (∅ 1.5)	RÜDE 1996
carbonatic rocks	0.1 - 20 (∅ 1.7)	RÜDE 1996
sandstones	0.6 - 120 (∅ 2.0)	RÜDE 1996
sandstones	100 – 200	LANDNER 1989
shales, shistshales	0.3 - 490 (∅ 14.5)	RÜDE 1996
shales	-900	LANDNER 1989
phosphorites	0.4 - 188 (∅ 22.6)	RÜDE 1996
pyrite	- 2 000	LANDNER 1989
pyrite	- 5 600	NRIAGU 1994 II
sedimetary iron ores	1- 2 900 (∅ 400)	RÜDE 1996
coals	0 - 2 000 (∅ 13)	RÜDE 1996
crude oil (world´s average)	0.134	RÜDE 1996
soil	**mg/kg**	**literature**
sandy soil	0.1 - 40 (∅ 5-6)	RÜDE 1996
peat	16 - 340	LANDNER 1989
soil from mineralized quarzites in Brisbane (Australia)	100 - 200	RÜDE 1996
soil from contact metamorphites from Dartmoor granites	250	RÜDE 1996
soil above sulfide deposits	8 000	LANDNER 1989
soil above gold ores in Zimbabwe	20 000	RÜDE 1996
atmosphere	**µg/L**	**literature**
precipitation	trace	EMSLEY 1992
precipitation	0.2	CARSON et al. 1986
precipitation	0.005 - 0.1	NRIAGU 1994 II
precipitation	0.01 - 5	LANDNER 1989
water	**µg/L**	**literature**
Atlantic surface	1.45	EMSLEY 1992
Atlantic deep	1.53	EMSLEY 1992
Pacific surface	1.45	EMSLEY 1992
Pacific deep	1.75	EMSLEY 1992
groundwater	0.01 - 800	LANDNER 1989
groundwater near polymetallic deposits	several 100,000	LANDNER 1989
fresh water (not contaminated)	0.15 - 0.45	RÜDE 1996
brackish water	1-2	LANDNER 1989
mineral water	7.5 – 22.5	NEUHAUS 1994
thermal water	20,000 – 3,800,000	NRIAGU 1994 II
heap sewage water	5-1600	MERKEL & SPERLING 1998

Besides the geological sources there exist different man made ones. Men early learned to use arsenic for his purposes. One of the most prominent applications of arsenic are the numerous poisonings with inorganic arsenic trioxide that started with Nero´s poisoning of Britannicus to secure his Roman throne in 55A.D. and was very popular especially in the Middle Age due to its availability, low cost and the fact, that it is taste- and colorless. Famous poisoners were Borgia pope Alexander VI and his son Cesare Borgia, Teofania di Adamo, Marie Madeleine. The popularity of the "inheritance powder" came to an abrupt end when in 1836 the development of Marsh´s assay created a possibility to prove arsenic in the bodies. 1842 the first poisoner to convict was Marie Lafarge for the murder of her husband (NRIAGU 1994 II).

But arsenic was also used since more than 2000 years as a medical remedy. Asiatic pills, Donovan´s solution, Fowlers solution or DeValagin´s elixier were considered to be a specific therapy for anorexia and other nutritional disturbances, neuralgia, rheumatism, asthma, chorea, tuberculosis, diabetes, intermittent fever, skin disorders, hematologic abnormalities. Until the end of the 19th century arsenic was used for embalming corpse, with a special boom during the Civil War from 1860-1865 (FETTER 1999). By the early 1900s physicians began using less toxic organic preparations of arsenic (sodium cacodylate, sodium arsanilate) for the treatment of pellagra, malaria and sleeping sickness. In 1909 Ehrlich´s experiment lead to the widespread use of arsphenamine (salvarsan) called "606" as principal drug in the treatment of syphilis, until its replacement by penicillin (NRIAGU 1994 II). The importance of arsenic in medicine has reduced but still it is used in some pharmaceuticals and especially for cosmetics.

The main application branch today is the agriculture. Phenylarsenic compounds for example serve as an essential trace element as a growth promoter for swines and poultry. Until at least the late 1960s in many southern states of USA there was an extensive use of arsenic solution in big dipping vats to eradicate ticks on cattle. Furthermore arsenic trioxide is used in tanning, taxidermy and wood preservation. Many arsenic herbicides exist like sodium arsenite, methylarsonic acid and dimethylarsinic acid, especially for the control of Johnson grass (Sorghum halepense) growth in cotton fields. Very spectacular was the use of dimethylarsinic acid known as "agent blue" as defoliant for military purpose in Vietnam. Arsenic bearing fungicides, insecticides (like Paris Green, cuprous arsenite used to control the Colorado potato beetle in eastern USA or lead arsenate against the fruit flies) and especially pesticides also are widely distributed (NRIAGU 1994 II). 1974 40% of the total arsenic emission to the ecosystem was due to pesticides (RÜDE 1996).

Technically arsenic serves as an additive for alloys to raise hardness and brittleness. Gallium and Indium arsenide is used as a semiconductor material superior to silicon. In the glass industry 0.2 to 1.0% of arsenic present as an additive a decolorizing agent (NRIAGU 1994 II), in the tanning industry it is used for depilation (MERKEL & SPERLING 1998).

Arsenic is also a by-product of smelters (especially Cu, Ni, Pb, Zn) and during roasting the ores gaseous As_4O_6 is produced which is distributed in the fumes up to 100 km. The same process occurs with coal combustion (CARSON et al. 1986) or also waste combustion.

In the middle of the 1980s the world arsenic production (as arsenic trioxide) was about 75,000 - 100,000 tons (NRIAGU 1994 II). The main arsenic producers are China, France, Germany, Mexico, Namibia, Peru, Sweden (20,000 t/year), USA, USSR (90% of the total production). The USA consumed about half of this world production, mainly in the agriculture sector (LANDNER 1989).

In Fig.31 the global arsenic cylce is shown both with man made as well as with natural emission sources, the later ones only making up ¼ of the total arsenic load.

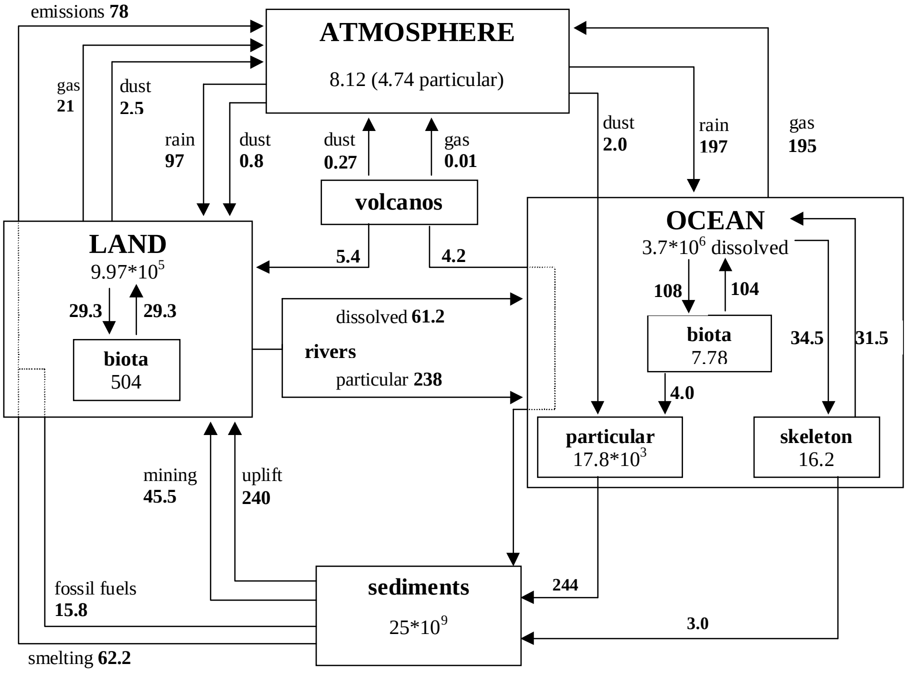


Fig. 31 Global arsenic cycle with natural and man made emissions [annual mass flow in kt/a, reservoir contents for atmosphere, ocean, land and sediments in kt] (according to RÜDE 1996)

2.4.3.3. Toxicology

As with many transition elements, the meaning of arsenic as an essential element for the human body is not totally proved. NEUHAUS (1994) questions arsenic to be essential, NRIAGU (1994 II) states <0.2 mg/day to stimulate growth and increase viability. On the other hand the toxic level is more apparent.

Whereas metal arsenic and the barely soluble arsenic sulfide compounds are more or less intoxic, As(III) has a high toxical potential, 25 to 60 times higher than As(V) and several 100 times higher than methylated compounds in contrary for example to Hg where organic compounds are much more toxic than inorganic ones. This is owed to the fact that As(III) is capable to react with sulfurhydryl groups increasing the biological lifetime in a human body (MERKEL & SPERLING 1998). Contrary to this general held view that arsenite is more toxic than arsenate LANDNER (1989) reports for algae cultures that under low phosphorous conditions arsenate is at least ten times more toxic than arsenite, whereas under high phosphorous conditions the toxicity of arsenate is also insignificant compared to arsenite.

The toxic intake of arsenic trioxide is 5-50 mg, 50-340 mg are a lethal dose (EMSLEY 1992). NRIAGU (1994 II) reports 200-300 mg of arsenic trioxide to be fatal, yet a dose of 20 mg has been recorded life-threatening and recovery from 10 g has also been reported. For arsine (AsH_3) the lethal exposure is 30 minutes with 250 mg As per m^3 air (RÜDE 1996).

The intake can either be through inhalation or through the gastrointestinal tract. Once insides the human body arsenic is distributed to the tissues by the blood (particularly to the liver, kidney, lungs, spleen and skin, in lower concentrations in bones and muscles), accumulated in fat including neutral tissue components that are high in lipids, phospholipids or phosphatides and finally exreted in the urine, the feces and by the dermis as shed skin, hairs and nails (CARSON et al. 1986). About 95% of the sorbed arsenic will come to the gastrointestinal tract and 70% of this will be excreted, probably As (V) easier and faster than As (III). The biological half-life of arsenic in the body reaches several weeks (NEUHAUS 1994).

The arsenic levels in a human body are 0.009-0.65 ppm in muscles, 0.08-1.6 ppm in bones, 0.0017-0.09 mg/dm^3 in the blood and the total mass of the element in an average (70 kg) person should be around 18 mg (EMSLEY 1992).

In a human body arsenate acts as an analog of phosphate indistinguishable for biota and can disturb central regulatory processes in the biological system concerning genetic (nucleic acids), hormonal (cAMP), energetic (ATP) or enzymatic (substrates and protein phosphorylation) codes. Arsenite possesses a high affinity for the sulfydryl groups of amino acids such as cysteine and thereby inactivates a wide range of enzymes in intermediate metabolism (FENDORF et al. 1997). According to NRIAGU (1994 II) As (III) is between 2.9 and 59 times more potent than As (V). The most toxic form is arsine gas, followed by inorganic trivalent compounds, organic trivalent compounds, inorganic pentavalent compounds, organic pentavalent compounds and elemental arsenic.

The resulting diseases are various: Throat discomfort, difficulty in swallowing, abdominal discomfort, nausea, chest pain, vomiting, watery diarrhea, systemic collapse due to severe hypotension, restlessness, convulsions, coma and death, often cardiac failure. Chronic exposure may cause carcinogenesis, cardiovascular disease, neurological effects, skin lesions, acute dermatitis, mottled skin, swelling, itching, sometimes papular and vesicular eruptions, melanosis (first on eyelids, temples, neck, areolae of the nipples, folds of the axillae), hyperkeratosis, hyperhidrosis, warts, peripheral neuritis of upper and lower extremities (sensory disturbances, muscular weakness, paralysis), anemia, leukopenia. Teratogenic effects are known on animals and suspected on humans. Mutagenic changes occur due to chromosome aberrations due to interferences with normal DNA repair processes. Skin and lung cancer are known to be caused by exposure to high arsenic contents (CARSON et al. 1986).

In general arsenic is the most common source of acute heavy metal and metalloid poisoning and is second only to lead in chronic ingestion. Fewer than 250 cases of arsine gas poisoning have been reported in the past 65 years, half of which were fatal (NRIAGU 1994 II).

Probably interactions of fluoride and arsenic engrave the toxicity since both elements affect enzyme activity in the glycolytic tricarboxylic and heme metabolism pathways (NRIAGU 1994 II). A lack of phosphorous may also increase arsenic toxicity. For fresh water algae LANDNER (1989) reports that phosphorous limited cultures have been 44 times more sensitive to arsenate-mediated inhibition of photosynthesis than cultures with sufficient or excessive phosphorous like marine or brackish water algae.

Meanwhile selenic should be capable of reducing perhaps even eliminating the carcinogenity of arsenic (LANDNER 1989). NRIAGU (1994 II) also emphasizes that arsenic and selenium act as antagonists, arsenic protects against selenium poisoning when arsenic is administered in the drinking water and selenium in the diet. Inorganic arsenic compounds shall decrease the toxicity of inorganic selenium compounds by increasing biliary excretion, but the toxic effects of methylated selenium compounds is markedly enhanced by inorganic arsenicals (NRIAGU 1994 II).

According to DAS et al. (1996) Vitamin C and methionine may also reduce toxicity, as well as high carbohydrate, high protein or even high fats diets protect against the toxic effect of arsenic. A medical antidote to arsenical poisoning is BAL (British Anti-Lewisite, 2,3dimercaptopropanol). Highly reactive thiol groups form cyclic dithioarsenites, which are more stable than the protein-thiol arsenites, thus preventing the negative enzymatic effects.

2.4.3.4. Restrictions and limitations

Due to the proved toxicology of arsenic some restrictions and limitations have been fixed. The dietary arsenic range should be 0.15-0.4 mg/person/day. For a 70 kg reference man this would be 1.0 mg/day from fluids and food and $1.4*10^{-3}$ mg/m^3 airborne intake considered losses from urine of 0.05, feces of 0.8 and others of <0.16 mg/day (CARSON 1986). 1981 OSHA (Occupational Safety and Health Administration) set 0.5 mg As/m^3 for organic and 0.01 mg/m^3 for inorganic arsenic compounds as limits. The workroom air 8 hour exposure should be less than 0.2 mg As/m^3 for arsenic metal and soluble compounds (CARSON 1986).

For soils the Netherland list contains 29 mg/kg as reference value, 55 mg/kg as intervention value. The Kloke value is 20 mg/kg (NEUHAUS 1994). LAWA (1994) considers 2-10 mg/L as reference range and 20-60 mg/L as intervention range.

Concerning drinking water the upper level of As is 0.05 mg/L in Mexico (DOF 1996) and was reduced from 0.04 mg/L to 0.01 mg/L in Germany (effective 1.1.1996). WHO (1993) also sets 0.01 mg/L as MCLG (maximum contamination level goal). United States´ EPA will change their drinking water level of 0.05 mg/L until the end of 2001. The new limit is not known yet but it will be between 0.001-0.02 mg/L. Water for watering animals should have less than 200 mg/L, but also 5000 mg/L have been read (MATTHESS 1990). The US EPA (1973) states arsenic contents of less than 1000 mg/L as suitable for irrigation water.

In Germany laws also restrict the application of arsenic bearing chemicals like the law for colors (1977), the pesticide law (1980), the cosmetic law (1985) and the law for cultivated plants protection (1986) (Schlussbericht für das Bayerische Landesamt 1988). There is nothing known about similar laws in Mexico.

2.4.3.5. Arsenic removal

To remove arsenic from water several methods are approved. A quite simple and cheap method is the alum coagulation method that allows about 70% removal of arsenic. 300-500 grams of alum wrapped in a clean cloth has to be sunk in a bucket full of arsenic contaminated water for 12 hours. The upper 2/3 of the water is separated by using a decanter or two layered clean cloth. The lower third of water contains arsenic and is not suitable for drinking (http://www.who.int/peh-super/Oth-lec/Arsenic/Series2/003.htm).

Another more efficient way is using the natural sorption of arsenic on activated clay minerals, iron or manganese oxides. An earthen column packed with iron oxide - manganese dioxide has just to be attached to the well outlet. The method is claimed to remove a significant amount of arsenic at water flow rate of 90-110 ml/minute and can filter up to 5000 liters of water before disposal. (http://www.who.int/peh-super/Oth-lec/Arsenic/Series2/003.htm). FENDORF et al. (1997) and EICK et al. (1997) describe their sorption method on hydrous oxides of iron (goethite) as a double relaxation event. During the first step an initial ligand exchange reaction occurs of aqueous oxyanions species $H_2AsO_4^-$ with OH-ligands at the goethite surface forming an inner sphere monodentate surface complex. The second step serves for a second ligand exchange reaction resulting in the formation of an inner sphere bidentate surface complex.

Arsenic sorption with activated aluminum is relatively well known and commercially available but presents some problems due to the necessary re-adjustment of the pH (http://www.who.int/peh-super/Oth-lec/Arsenic/Series2/003.htm).

According to Schlussbericht für das Bayerische Landesamt (1988) oxidation with chlorine or flotation with long chained surface activated alkyle derivates at pH 7 are other possibilities. Lanthan compounds shall also be very effective for arsenic removal as As(V) (TOKUNAGA et al. 1997).

Generally all these coagulation or sorption techniques have the disadvantage of requiring either a daily removal or periodical regeneration of the toxic sludge or sorption material. Membrane techniques like reverse osmosis or electrodialysis are superior to this, having a high removal efficiency, low space requirement, producing no solid waste and being capable of removing other existing contaminants too. But since they involve high investment and maintenance costs, they probably won´t present a real alternative, especially not in poor countries. (http://www.who.int/peh-super/Oth-lec/Arsenic/Series2/003.htm).

2.4.3.6. Arsenic in Mexico

In Mexico some areas of naturally high arsenic contents are known. NRIAGU (1994 II) names sites in the states Chihuahua, Puebla, Nuevo Léon and Morelos (Fig.1).

Since 1963 arsenic occurrence is also known from the region Comarca Lagunera an important cotton producing semiarid area in the central part of Mexico (states of Coahuila and Durango). Other important economical branches are mining and dairy products. In 1992 73 wells, soil, milk and forage were analyzed for arsenic. The arsenic contents in the aquatic system varied between 7 and 740 μg/L, 90% of which in the pentavalent form. The alcaline (pH>8) sandy clay loam soil samples low in organic matter showed values from 11 to 30 mg/g in the upper 30 cm of the strata, but only less than 15 mg/g of this extractable. The source of this arsenic anomality are magmatic hydrothermal processes with a general increase in elements like lithium, boron, fluoride and arsenic (ROSAS et al. 1997)

Suspected already in the early 1980s but detected not before a water sampling program for cholera bacterium in 1992 Zimapan (state of Hidalgo) in the semiarid basin of the river Panuco, the main drain of the river "rio Verde", is also an area enriched in arsenic. The basin´s geology resembles the one from Rioverde. An old carbonate platform is overlain by jurassic, mainly cretaceous limestones. Tertiary rhyolites and basalts intrude in this geological frame creating metamorphic zones like skarns in limestone and hornfels aureols in shales inside the basin. The interior pleistocene basin fill consists of alluvial fan deposits covered by caliche.

Even the hydraulic conditions are quite similar. Two aquifers exist, an upper pleistocene one and a deeper cretaceous one partly showing hydraulic communication. The main recharge comes from the surrounding mountains only a negligible part from precipitation in the valley. The river Tolimán presents a hydraulic barrier dividing a northern part from a southern one.

In this area 3 main contamination sources are known. The one with the highest arsenic concentrations (0.014-1.097 mg/L) derives from natural oxidation and dissolution of arsenic bearing minerals and is connected to some of the deep wells (-180 m) in the cretaceous aquifer. The volcanic rocks themselves showed no arsenic increase. Concentrations up to 0.437 mg/L and 0.10 mg/L occurring in the swallower wells (5-15 m) are traced back to man made sources. On the one hand this is leaching of old mining tailings from Au, Ag, Cu, Zn and Pb mining with the by-product arsenic, on the other hand soil infiltrations from arsenic rich smelter fumes (ARMIENTA et al. 1993 & ARMIENTA et al. 1997).

3. PROCEDURES AND METHODS

Chapter 3 deals with the "technical" aspect of the work showing what was done (procedures) and how it was done (methods).

3.1. Geology

Detailed geological mapping originally was no objective of this master thesis but since the official geological maps 1:50,000 and 1:250,000 ("Carta geologica" F14-C16 El Refugio, F14-C17 Rio Verde, F14-A87 San Francisco, F14-A86 Angostura (CETENAL 1976) and "Carta geologica" F14-8 Ciudad Valles, F14-7 Guanajuato, F14-5 Ciudad Mante, F14-4 San Luis Potosi (CETENAL 1983)) turned out to be wrong in some locations where they were arbitrarily checked a short field campaign was done checking several outcrops and taking some rock samples for analyzing the chemical composition of the rock extracts and in one case the rock age. Further geological information was supplied by geophysical cross-sections from 3 previous projects and drilling informations from 2 previous projects. Only part of one drilling was attended personally. The information of 6 geological crosssections from COMISION FEDERAL DE ELECTRICIDAD (1984) unfortunately couldn´t be used since the corresponding map was missing.

3.1.1. Outcrops and rock examinations

During about 20 days 55 more or less accessible (to reach by car) outcrops from all formations (Cretaceous El Doctor - Quarternary) were checked in an area of 35 x 28km. Special attention was paid to a formation that was mapped as "Tertiary conglomerate" in the geological maps and couldn´t be confirmed surely in any of the examined outcrops. Another point of interest was the Quarternary since until 1999 no map or paper existed presenting a detailed idea of the Quarternary development and consequent distribution of the corresponding sediments.

For the analysis of the rocks´ chemical composition samples were taken from El Doctor limestone, Quarternary tuff, tuff soil, travertine, caliche and clay for the simulated silicate weathering extraction, analyzed with ICP-MS (App.No.17) and from Quarternary gypsum and chalk for extraction with deionized water, analyzed with IC (ion chromatography) (App.No.18). Age determination with thermoluminiscence was only done for one sample (Quarternary tuff) due to lacking funds. The location of the sampled sites can be seen in the digital tntmips atlas [file geology, rock_samples].

3.1.1.1. Simulated silicate weathering - extraction

The rock extractions mentioned above were done at the University of Mining and Technology in Freiberg, Germany after grinding the rocks to fine powder. For ICP-MS determination the extraction solution consisted of 500 ml 0.2 M ammoniumoxalate mixed with 0.2 M oxal acid to pH 3 for 5 g dry sample. This chemical reaction is the 5.step of the sequential extraction from SALOMONS & FÖRSTNER (1980) and simulates an intensive silicate weathering with the dissolution of even strongly bound iron and manganese oxides and is more realistic than the often applied aqua-regia-extraction which distroys all compounds and doesn´t occur in nature. After stirring the solution for 24 hours, the residual mud had to settle down for 4 days. The solution above the mud was decanted, filtrated with 200 nm filters, stabilized with 25 drops of HNO_3 suprapur and the elements Ni, Cr, Cu, Zn, As, Cd, Pb, U, Th, Y, La, Ce, Pr, Nd, Mo, Sr, Ba, Mn, Al and Fe were determined at the ICP/MS laboratory in Tharandt/ Germany (App.No.17).

For the IC determination 5g powderized rock sample were diluted with 500ml deionized water and stirred for 24 hours. After the residual mud had settled the solution above was decanted and Cl, SO_4, Mg, Ca, Li, Na and K were determined with IC.

3.1.1.2. Thermoluminiscence

The principle of thermoluminiscence is determining the time of the rock´s last heating or light exposure. Therefore taking the tuff sample had to be done very carefully in order not to falsify the real age with today´s sunlight exposure. Since it was not possible to get a fresh cut a big tuff bloc of approximately 35x20x20cm with as little porosity caves as possible was taken from underneath the stack where it was protected from the sunlight, packed in cling film to protect the tuff from breaking apart, then in aluminium foil to protect it from sunlight and in two black plastic bags. At the university in Freiberg the bloc was cut in a dark laboratory, the outer shells were removed and only the inner unexposed part used for grinding the rock to 100-200nm grain size. The further determination was done at the "Saxonian Academy of Science", research section Quarternary geochronology in Freiberg. Since unfortunately the results were not ready when finishing this work, they will be published in a later paper.

3.1.2. Drillings and Geophysical Sections

Further information for the geological understanding was obtained from different geophysical cross-sections (1973, 1980, 1998) as well as from some drilling reports (1984, 1998 and 1999). Even though it was possible to have a look on the drilling samples, this was not very helpful since all the wells were drilled with a rotary rigg and the samples presented just a mixture of rock fragments with all clay or finer material washed out by the drilling fluid, e.g. the San Diego well showed 200 m of the same equally sized rock fragments. Thus it was preferred to rely on the geology documented during drilling as far as it was done.

3.1.2.1. Geophysics

3.1.2.1.1 Alvarado (1973)

ALAVARDO (1973) presented the interpretation of 5 horizontal geophysical cross-sections (A-E) combined from 42 vertical geoelectric sections [A = Media Luna - Rioverde - El Amagre, B = Bordo Blanco - Miguel Hidalgo, C = San Onofre - NW´ El Jabali, D = Ojo de Agua de Solana - El Amagre, E = Pastora - San Francisco]. The model used for the interpretation was a simple 3-layer-model distinguishing between Quarternary less and more compacted and underlying rock. The less compacted Quarternary was interpreted to be Travertine, Caliche or clay, sometimes also gravel and sand, the more compacted Quarternary was only refered to as "compacted, coarse material" with no further explanation. Considering the geological model of the basin this application of the same simplified 3-layer-model for the southern, northern and western part is totally inadequate. Unfortunately the original data were missing in the report, so it was not possible to do a reinterpretation.

The only information used from ALVARADO (1973) was the depth of the underlying rock in order to model the depth of the basin´s filling. Since numbers for the depth and the location (longitude/latitude) were missing they had to be recalculated from the copied cross-sections respectively from the topographical map with the corresponding inaccuracies.

3.1.2.1.2 Secretaria de Agricultura (1980)

The geophysical results of 3 horizontal cross-sections (P1-P3) from 26 vertical geoelectrical sections were reported in SECRETARIA DE AGRICULTURA (1980) [P1 = Loma Las Auras - Puerto de Colmenas, P2 = Puerta del Rio - La Gavia, P3 = Angostura - La Muralla]. The interpretation in 6 different layers was taken in agreement with the basin´s general geology and seems realistic (Fig.76, Fig.77). Wherever the bedrock was reached the depth information was used to model the depth of the basin´s filling (vertical sections 107, 108, 109, 110, 304, 308A; cross-section 2 was not considered for this since it was too far to the northwest, outside the studied area). Numbers for depth and location had to be taken from the copied cross-sections respectively the topographical map.

3.1.2.1.3 Cham (1998)

The data for these geophysical cross-sections originate from an entire geophysical measuring campaign started in 1998 to determine the best locations for new wells to be drilled in the southern parts of the basin. Mostly about 4 different vertical sections were determined on each site (SEV 1-4). The reports contained the interpretation of the single vertical sections as well as horizontal cross-sections connecting the 4 vertical drillings of each site. The information provided by these horizontal cross-sections was very good, corresponding well with the general geological idea. The sections in which the bedrock was reached were used to model the depth of the basin´s filling; the depth numbers were given in the report.

The different geophysical sites from W to S to NE were: Ojo de Agua de Solano (SEV1-3), La Tapona (SEV1-3), El Tecomates (SEV1-4), La Loma-Buena Vista (SEV1-4), El Jabali (SEV1-4), Las Magdalenas (SEV1-4), El Huizachal (SEV1-4) and La Muralla (SEV1-4). The coordinates for the different sites had to be taken from the topographical map since they were not surveyed with GPS.

3.1.2.2. Drillings

3.1.2.2.1 Secretaria de Agricultura (1984)

Secretaria de Agricultura (1984) provides a report with geological sections, well constructions and some technical information for several drilled wells in the whole state of San Luis Potosi. 5 sites (No.13, 20, 142, 142, 143) around Rioverde were used to extend geological knowledge of the basin´s underground. Well locations were taken from the topographical map.

3.1.2.2.2 Presidencia Municipal (1998)

The drillings from 1998 were conducted by two drilling companies and the reports provided by the Presidencia Municipal de Rioverde. The location of the drilled wells results from the geophysical measurements of CHAM (1998); well "El Huizachal" is drilled near SEV2 (cross-section El Huizachal), well "Tecomates" near SEV2 (cross-section El Tecomates), well "Las Magdalenas" near SEV2 (cross-section Las Magdalenas).

3.1.2.2.3 Sainacio (1999)

The only drilling attended personally in 1999 was the drilling Sainacio. Unfortunately the drilling was already at 100m depth and almost finished, but it was the only sampled drilling that was done without rotary rigg but with cable tool percussion drilling. Therefore silt and clay wasn´t washed out like in all the other drillings and a sample was taken for simulated silicate-weathering extraction. The missing geological record from the upper 100 m was obtained from the drilling master. The bore hole head was surveyed with GPS.

3.1.3. Tectonics

Since the geological outcrops of the hard rocks mostly showed only weathered blocs of limestone, basalt or rhyolith and no original rock surfaces it was not possible to do own tectonic measurements in the period of time invested for geology. It would have been possible in the nearby Sierra to the west (recharge area) where there are very good outcrops of limestone and rhyolith along the highway Rioverde - San Luis Potosi, but since this part is far west of the actual study area´s boundaries tectonic measurements there were not performed.

For the interpretation of the structural situation in the basin and it´s surroundings a satellite image and a true color, false color and shaded relief DEM (Digital Elevation Model, digital tntmips atlas [file topography, DEM]) was used in *tntmips* (App.No.7). The 1 km hydrological corrected DEM was obtained for free from the internet as part of the download file for Northamerica (http://edcwww.cr.usgs.gov/landdaac/1km/1kmhomepage.html). Basicly it was planned to work with a much more accurate 50 m DEM from INEGI which was however distributed so late and on 8 mm tapes which were impossible to process at the TU Freiberg that this idea was skipped in the very end.

Concerning the satellite image different Landsat images older than 10 years (lower price!) were checked through the quick looks for cloudcover and vegetation cover. The Landsat TM full scene 27/45 from 14.03.1986 was choosen and ordered from the USGS. The data were imported in *tntmips* and several false color images and the rasters for brightness, greenness and wetness were processed. A principal component analysis using all 7 channels and different cluster analysis were performed and have been put into the digital tntmips atlas [file topography, Landsat].

Tectonic information was mainly taken from the official geological maps 1:50,000 (CETENAL 1976) and the remapping of the sheet F14-C16 El Refugio (LABARTHE et al.1989). Rose diagrams of preferential directions were calculated by automatic directional analysis (chapter 3.1.4) for the whole southern basin area and two selected parts. The minimum length of considered structures was choosen with 10 seconds, which equals about 300 m and with a scale of 1:50,000 0.6 cm on the map.

3.1.4. Presentation of the geology

As a synthesis of all the above mentioned geological examinations and interpretations the following maps were drawn:

- geological maps and cross-sections sketching the basin development (Fig.81 a-d, Fig.82 a-c)
- 2 maps presenting the most important tectonic structures and geological results especially for the basin´s Quarternary (Fig.85, Fig.84),
- a model of the depth of the basin´s filling (Fig.83, digital tntmips atlas [file geology, depth_of_basin])
- a geological-tectonic map to scale containing the locations of the geophysical sections, the drillings and the outcrops (digital tntmips atlas [file geology]).

The depth of the basin´s filling was calculated with data from different projects (Presidencia Municipal de Rioverde 1998, ALVARADO 1973, SECRETARIA DE AGRICULTURA 1980 and 1984). The data base was quite small (75 points on an area of approximately 40x30km). To simulate the basin´s borders, 345 points were digitized from the vectorized geological map, where the underlying rocks outcrop (basin´s filling depth = 0). The depth modelling was done in *Surfer* (App.No.7) with the gridding method Kriging with linear variogram. The model itself is displayed in Fig.83 and as raster object in the digital tntmips atlas. The corresponding database is added in the digital atlas as extra layer with the number or name of the reference points and the depth of the Quarternary filling [file geology, depth_of_basin].

The geological-tectonical map was mainly developed from the official geological maps 1:50,000 (CETENAL 1976). The map was redrawn on 2 transparencies separating polygon´s of geological formations and lines of tectonic structures. The transparencies were scanned, imported to *tntmips* and automatically vectorized. The sheet F14-C16 El Refugio (CETENAL 1976) was amplified for tectonics and replaced for stratigraphy by the "Plano geologico de la Hoja El Refugio, S.L.P." from LABARTHE et al. (1989). The general stratigraphy is almost the same but LABARTHE et al. (1989) differentiate INEGI´s "acid extrusivas" in rhyodacites, dacites, andesites, ignimbrites. There are also some things that are totally different/wrong, e.g. the basalt at N 21°55´00´´ and W 100°17´00´´ in CETENAL (1976) is reported to be a dacite, the igneous rock at N 21°50´16´´ and W 100°00´46´´ a cretaceous limestone. At N 21°50´05´´ and W 100°05´27´´ as well as at N 21°51´44´´ and W 100°02´38´´ cretaceous limestone from CETENAL (1976) was remapped as dacite in LABARTHE et al. (1989), the CETENAL (1976) conglomerate around San Martin as uncemented gravel, sand and clay, whereas the rhyolith west of San Martin is presented as conglomerate in LABARTHE et al. (1989).

The vectorized tectonic map was used for the automatic directional analysis mentioned above (option in *tntmips)* over the whole map and in selected areas to obtain preferential fault or strike directions (Fig.80).

Besides the two layers for geology and tectonics, the geological-tectonical map presented in the digital tntmips atlas [file geology, geology respectively tectonics] includes 3 layers for the locations of the geophysical sections, the drillings and the outcrops. These 3 layers contain database with number or name of the locations, depth of the drilling, depth of the Quarternary sediments if bottom was reached and for the outcrops description of the geology. As additional information the official soil map ("carta edafologica", CETENAL 1976) is displayed as raster object [file geology, soil].

3.2. Hydrogeology

3.2.1. Natural hydrological cycle

3.2.1.1. Groundwater recharge

To calculate the groundwater recharge (GWR) for the study area according to the general equation P = ETA + R + GWR (P = precipitation, ETA = actual evapotranspiration, R = runoff) climate information from 5 different meteorological stations in the basin were used (App.No.1, App.No.2 and App.No.3, digital tntmips atlas [file hydrology, meteo_stations]). Except for Rioverde no coordinates were reported for these stations, thus they had to be calculated from the topographical map, assuming that the meteorological station is located in the middle of the village with the same name.

Unfortunately no data was available about soil moisture, soil moisture changes over time and soil depths. Thus soil moisture storage and it´s change over time was not taken into account. As well no data from stations located in the Sierra west of the basin (the recharge area) could be obtained.

Since it was not possible to quantify surface runoff (R) (except for the river rio verde), it was put together with the groundwater recharge (GWR). Actual evapotranspiration was calculated according to two different methods, TURC (GRAY 1973) and COUTAGNE (REMENIERAS 1974).

TURC: $ETA = P / [0.9 + (P/J)^2]^{0.5}$ $J = 300 + 25*T + 0.05*T^3$
with P = mean annual precipitation [mm]; T = mean annual temperature [°C]

COUTAGNE: $ETA = P - \lambda * P^2$ $\lambda = 1 / (0.8 + 0.14 * T)$
with P = mean annual precipitation [m]; T = mean annual temperature [°C]

For calculations with more complicate equations like MORTON or BUDYKO equation the necessary parameters were missing. Generally the ETA values obtained with the TURC equation were lower, for all 5 stations leading to negative GWR. With the Coutagne equation small amounts of GWR were obtained as expected in a semiarid area. This is concurrent with reports in BIRKLE (1998) according to which Turc equation always produced too low values (5-15%), Morton equation too high values, while calculations with Budyko or Coutagne produced reasonable results. Therefore the results with the Coutagne equation were taken and due to the semi-emipirical charachter of the equations a deviation of about ± 20-25% was assumed.

Using the salt balance method for the calculation of the groundwater recharge was impossible, since not only the data for chloride and/or bromide concentrations in rain water were missing, but at least in the area of intensive agricultural use around El Refugio chloride in the groundwater probably does not only result from atmospheric salt but also from fertilizers.

For calculation of the superficial recharge area the 1 km DEM raster object was used in *tntmips* with automatic calculation of the watersheds (digital tntmips atlas [file hydrology, watersheds]). Due to the lack of more information the subterranean recharge area was supposed to be equal with the superficial.

To get an idea of the groundwater recharge outside the basin, where there were no meteorological stations at all, temperature and precipitation were extrapolated for each raster cell of a DEM cut of the area according to the simplification that temperature decreases by 0.47 °C per 100 m and precipitation increases by 7 % per 100 m (TERTILT & MERKEL 1993). For reference temperature and precipitation at 1000 m altitude were calculated as an average of the 5 meteorological stations in the basin. Actual evapotranspiration was calculated according to the Coutagne equation and groundwater recharge as the difference of precipitation and actual evapotranspiration. For the corresponding SML (spatial manipulation language) script in *tntmips* see App.No.20. The calculations had to be done separate for the 12 months and the 12 rasters were combined to one for the annual groundwater recharge. Then this raster was cut along the 5 catchment areas (1, 1a, 1b, 2a and 2b, Fig.86) and the area of each catchment area in km^2, the average groundwater recharge in $mm/(a*m^2)$ and the total groundwater amount in m^3/s were calculated by a SML script.

3.2.1.2. Hydrogeological settings

Pumping tests from previous projects (App.No.21) unfortunately provided not enough data for calculating the kf-value from the reported transmissivity. As first approximation the well depth minus 10 m was assumed to correspond to the length of the well screen (fully penetrated wells provided). The obtained kf-values of 10^{-4} to 10^{-5} m/s seemed to fit well for the southwestern area (El Refugio) with fluvial sediments. However for the chalks in the northwestern part (Pastora) the same kf-values (wells 389 and 395) seems to be too high.

To get an idea of the distribution of the basin´s aquifers 85 wells in the study area were inspected. In 62 of them the groundwater tables could be determined in June 1999, additionally data from 7 previous projects were collected (App.No.22, for the location of the wells see digital tntmips altas [file hydrology, GW_tables]). The data from the SECRETARIA DE AGRICULTURA reports (1972: 102 wells, 1980: 313 wells) and ALVARADO (1973: 33 wells) included groundwater table "interpretation maps" that were not used since they showed several inconsistencies like a 100 masl isoline inside a closed 900 masl, open isolines, isolines ending just before isolines with higher or lower values etc.

Longitude and latitude values were not given and had to be digitized from printed maps with the corresponding inaccuracies. Altitudes for the wells examined in 1980 had to be reconstructed in *tntmips* by converting the 2D-vector object in a 3D-vector object using the altitudes from the wells examined in 1972 as reference raster. The 1972 altitude raster model was calculated with triangulation, thus no extrapolation was made and no altitudes were obtained for 1980 wells lying outside the area examined in 1972 ("---" in App.No.22). The same procedure was done for the wells examined in 1999.

Supposed additional data from MONTANEZ (1992) turned out to be just uncited copies from SECRETARIA DE AGRICULTURA (1980). Data from 1986 (13 wells), 1996 (44 wells), 1997 (51 wells) and 1998 (50 wells) were obtained from CNA already including longitude, latitude and altitude.

As App.No.23 shows the data distribution and density is very different within the 8 data sets, the lowest data density in 1986, the highest in 1980. The modeling of isolines was done in *Surfer* with the gridding method Kriging with linear variogram. To avoid algorithm artefacts due to extrapolation over large areas with no or little data, the whole area was divided in two smaller ones (N 22.08° - 22.14°, W -100.10° to -100.02° (around Pastora) and N 21.90° - 22.0°, W -100.12° to -100.03° (around El Refugio)) with higher data density.

For Pastora area the results from 1996, 1998 and 1999 were used to plot contour maps of the groundwater tables, 1972 and 1986 were skipped due to low data density, 1980 and 1997 produced algorithm artefacts due to unequal distribution of the data. For El Refugio area the data density was much better, except for 1986 all reports were used with 54 wells (1972), 29 wells (1973), 188 wells (1980), 18 wells (1996), 19 wells (1997), 21 wells (1998) and 48 wells (1999) [the maps from 1972, 1973, 1980, 1997 and 1999 presented in chapter 5.1.1 may display less wells, because in order to get comparable parts all maps were equally cut at N 21.90° - 22.0°, W -100.12° to -100.03°, though for calculating the isolines nearby points outside this frame were also considered].

3.2.2. Man made changes in the hydrogeological settings

To visualize man made changes on surface water differences in the yields of the rio verde determined at the inlet (Nogal Obscuro) and at the outlet (Vigas) of the basin from 1964 to 1992 were compared. To visualize effects on groundwater the development of the groundwater tables from 1972 to 1999 was pursued. Since for Pastora area the data density was too low to plot automatically calculated contour maps of differences in the groundwater tables between different years only time series of single wells were selected with 3 or more records over the years 1972, 1973, 1980, 1986, 1996, 1997, 1998 and 1999. Unfortunately the numbering was only consistent in the years 1972, 1973 and 1980, different from the one from 1986-98. Since only few wells were marked with numbers or signs it was also impossible to determine corresponding numbers in the 1999 field trip, so 3 different numbering sytems exist. Taking into consideration the uncertainties in determining the well locations a deviation of ± 250m was regarded as one well if the groundwater tables showed reasonable correspondences. For El Refugio area the data density was high enough to calculate maps with the program *Surfer* showing the development of the groundwater table between different years.

3.3. Hydrochemistry

3.3.1. Description of the sampling locations

For detailed hydrochemical investigations two different regions in the basin were choosen: El Refugio southwest and Pastora north of Rioverde. The well locations can be seen from in the digital tntmips atlas [file hydrology, sampled_wells].

"El Refugio" area named after the village El Refugio about 5 km W of Rioverde is located in the eastern part of a region of intensive irrigation agriculture mainly growing oranges, chili and corn measuring about 6 km west-east and 12 km north-south.

In this region 6 active wells from SASAR (Organismo Operador Paramunicipal de Agua Potable, Alcantarillado y Saneamiento Descentralizado de las Autoridades del Ayuntamiento de Rioverde, S.L.P.) are located guaranteeing Rioverde´s drinking water supply (namely P3, P9, P12, P16, P17, PSD, PSM) plus two that were out of order in summer / autumn 1999 (P2 and P10 with a small house serving as field base for all the SASAR wells).

The water from all wells is collected in one main pipe and conducted to Rioverde parallel to the highway San Luis-Rioverde. Chlorine is added to this main pipe, besides this there is no further water treatment for the drinking water. The water is stored in 2 tanks of 300 m^3 and 600 m^3 in 20 m altitude and distributed from there. The drinking water distribution net work is about 32 years old (TACSA 1998).

The waste water is collected in 3 big collectors, ending in the southeastern part of Rioverde in an open channel discharging to the river without any waste water treatment (Fig.32).

Fig. 32 Rioverde´s waste water discharge (from the right) to the originally green river "rio verde"

The 2 drinking water wells for Ciudad Fernandez (La Mezclita and Chilera) are also located in the El Refugio area. In addition numerous private and public wells extract the water needed for the intensive irrigation (estimated more than 300 deep and shallow wells).

In contrast to this the second area "Pastora" named after the village Pastora 25 km NNW of Rioverde is much poorer. Only few farms are located there with a more extensive and isolated agriculture. Large areas are dry and covered only by mezquites and cactus. Drinking water is delivered by water trucks since the groundwater is not potable. About 2 km SW from Pastora there is a quarry were tuff is mined as road building material. At the very moment the region is changing its face with the construction of the new highway from San Luis to Tampico.

3.3.2. Sampling

From El Refugio 8 drinking water wells (P3, P9, P12, P16, P17, PSD, PSM, Chilera) and 6 irrigation water wells (Doña Matilde, El Peloteado, El Encinito I, El Encinito II, Las Guayabas and Huerta los Piños) were sampled, from Pastora 9 irrigation water wells (La Cabaña, Pastora, Chamizal, Vergel I, Vergel II, La Gloria, San Isidro, Santo Domingo, Rancho #13). The sampling was done two times, first in June/ July and a second time in October (App.No.24).

pH, temperature, conductivity, redox potential (E_H) and oyxgen were determined in a flow-measuring-cell connected with a hose to the well valve. Where no valve was available (Las Guayabas, Chamizal, La Gloria, Santo Domingo and La Cabaña) the hose was stuck in the open discharge pipe. E_H and oxygen were measured in 5-minute time steps until the value had stabilized (sometimes more than one hour).

Besides phosphate, nitrate, nitrite, ammonium, total iron, iron(II), hydrogencarbonate and carbondioxide were determined in the field. Arsenic was sampled in an extra PE bottle and determined each evening.

For laboratory analysis the following amounts were taken in PE bottles: 1 L unfiltrated, unstabilized for anion determination, 0.5 L unfiltrated, stabilized with HNO_3 for cation determination, 0.125 mL unfiltrated, stabilized with H_2SO_4 for nitrate determination and 0.125 mL unfiltrated and unstabilized for a second arsenic determination in the laboratory. For ICP the water was filtrated with 200 nm filters, stabilized with suprapur nitrate acid and kept in 50 ml glass bottles. For tritium water was sampled in 250 ml PE bottles and for deuterium/oxygen in 50 ml glass bottles without stabilization. All the samples were tried to keep cool and dark until the final analysis in the laboratory.

In addition to the above mentioned 23 wells from El Refugio and Pastora, 4 springs were sampled. From Anteojitos, Ojo de Agua de Solana and Charco Azul samples were just taken from the surface trying to avoid too heavy pollution from bathing or animal watering. For Media Luna an own sampling program was conducted since it is fed by at least 6 different springs in 2 to 36 m depth as mentioned before. To find out if these springs in different depths spill water from different horizons or recharge areas a diving-sampling tour was done and the PE bottles for laboratory analysis were filled under water in front of the respective outlets. Temperature was measured directly at the spring outlet with a diver´s thermometer. PH and conductivity were determined afterwards in an open vessel. E_H and oxygen could not be measured under reproducable conditions and thus were skipped. App.No.24 shows the corresponding results.

For all the wells and springs as many information as possible were collected, concerning environment, well equipment, groundwater table and former chemical analysis (Appendix - mapping, well and spring description). App.No.6 contains a detailed list of the applied determination methods for all elements. In the following only pesticides and elements where problems showed up are mentioned.

3.3.2.1. Selected and problematic chemical determinations

3.3.2.1.1 Nitrate

During the first sampling in El Refugio nitrate was determined in the field with the HACH photometric methods (3 different methods for high, medium and low NO_3 concentrations). Compared to the results from the laboratory ultraviolet spectrophotometric screening method the field results were almost always lower (except for P9 and P17) especially in the higher concentration range (Tab.5). The results from the ultraviolet spectrophotometric screening method were checked with IC and confirmed. Thus the HACH photometric method was checked with an own calibration solution and the original one from HACH in double determination. Surprisingly the validation accuracy was quite good in the low concentration range up to 4mg/L contrary to the high differences in lab and field results for P12, P16 and Las Guayabas. In the high concentration range the validation results were always too high conflicting with the field results being lower than the laboratory results (Tab.5). Decalibration or malfunction of the photometer can be excluded since a HACH photometer from the laboratory in the university Rioverde showed the same concentrations. Since it was not possible to solve the problem the field determination of nitrate was skipped for Pastora area.

Tab. 5 Comparison of nitrate field and lab results from El Refugio sampling area and nitrate validation [solution 1: 100 mg/L N-NO_3 (72.18 mg NO_3 for 100 ml) standard solution, dilution to 10, 8, 4, 2, 1, 0.4 mg/L; solution 2: nitrate nitrogen standard solution ampoule pk/1 500 mg/L as NO_3-N (cat.14260 - 02 HACH), 0.1 ml for 25 ml = 2 mg/L, 0.2 ml for 25 ml = 4 mg/L, 0.3 ml for 25 ml = 6 mg/L] [mc = HACH method for medium concentrations, hc = HACH method for high conc.]

mg/L	**P3**	**P9**	**P12**	**P16**	**P17**	**PSD**	**Chilera**	**El Peloteado**	**Encinito I**
lab	43.41	35.42	1.45	4.52	10.67	16.52	29.06	36.01	10.66
field	34.111 hc	41.199 hc	0.6202 mc	0.9303 mc	14.619 hc	15.062 hc	20.821 hc	19.492 hc	9.746 hc

validation	**standard [mg/L]**	**10**	**8**	**6**	**4**	**2**	**1**	**0.4**
solution 1	high concentrations (hc) 1st determination	13.4	9.9					
	high concentrations (hc) 2nd determination	13.3	9.9					
	medium concentrations (mc)				4.1	2.0	1	0.5
	medium concentrations (mc)				3.7	2.1	1	0.4
solution 2	1st determination mc			6.9	4.4	1.9		
	2nd determination mc			6.8	4.4	2.2		

3.3.2.1.2 Ammonium

Ammonium was also determined with a HACH photometric method. The concentrations were generally low, concentrations of more than 1 mg/L showed not the expected yellow color as indication of NH_3 but just a milky dullness, probably due to some interference. Since it was not possible to eliminate this problem either, NH_3 was not determined further on.

3.3.2.1.3 Iron

A special problem occurred with iron. Both total iron and iron(II) were determined with HACH photometric method. In the first sampling in 6 out of 13 wells iron(II) showed higher concentrations than total iron. These results were confirmed with double and sometimes even triple determinations. Even after 200 nm filtration iron(II) was still higher than total iron (Chilera: Fe(total) = 0.05 and 0.06, Fe(II) = 0.11 and 0.09 mg/L, Huerta los Piños Fe(total) = 0.01, Fe(II) = 0.07). The validation with the HACH standard ampoules showed quite good results (Tab.6), so decalibration of the device can be excluded. Thus during the first sampling iron was not determined further in Pastora area.

Tab. 6 iron validation [iron standard solution ampoule pk/1 50 mg/L as Fe (cat.14254 - 02 HACH), 0. 1ml for 25 ml = 0.2 mg/L, 0.2 ml for 25 ml = 0.4 mg/L, 0.3 ml for 25 ml = 0.6 mg/L]

standard [mg/L]	0.2	0.4	0.6
1st determination	0.19	0.41	0.59
2nd determination	0.21	0.38	0.59

During the second sampling campaign all wells were determined again for iron; 20 out of 24 showed higher Fe(II) than total Fe concentrations. It was remarkable that the solution from Fe(II) determination was often dull while the solution from total iron determination showed no interferences at all. This seems especially strange since the chemical reaction mechanism is the same for both procedures. No possible interfering ion could have been found, all cited interfering ions in the HACH description only show effects in much higher concentration ranges. An exaltation of the reagents´ buffer capacity due to strongly buffered water is unlikely since the sample Vergel I with pH 8.45 and almost no buffer capacity also shows much higher Fe(II) than total Fe concentrations.

3.3.2.1.4 ICP-MS elements

For the June/July samples Li, B, Al, Mn, Fe, Cr, Co, Ni, Cu, Zn, Cd, As, Se, Sr, Sb, Ba, Sc, Y, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Tl, Pb, Th and U were determined with ICP-MS and some surprisingly high concentrations were detected (App.No.24a-c). Especially uranium concentrations of 1357-1986 µg/L seemed quite unbelievable, therefore a sampling collective of 3 mixed samples was measured a second time in the ICP-MS laboratory Tharandt and the high concentrations in the one collective were reproduced. Additionally the 4 samples with the highest uranium concentrations (from the same sampling date but kept in other bottles) were measured in Freiberg with photometry but the increased values couldn´t be confirmed (measured concentrations of 41-75 µg/L, probably even lower since the calibration line was calculated from concentrations more than 500 µg/L and normally the calibration line becomes steeper in the lower concentration range). A second determination of the 4 samples in Tharandt showed concentrations of 407-657 µg/L, lower than the first determinations by the factor 1.5, but still about 10 times higher than the photometric results. Contamination of the 4 bottles from previous sampling seems not probable since the discrepancies are so high; another contamination source could not be found.

Increased concentrations also occured for the elements Li (Pastora samples), B (Pastora samples), Al (P12, El Peloteado, Santo Domingo, Vergel II, Rancho #13), Mn (P12: 1378.3 µg/L), Cr (Anteojitos), Co (P12, San Isidro), Ni, Cu (P12), Zn (P12), As, Se, Sc, Ce (El Encinito I, El Peloteado, P12, Santo Domingo, Vergel II) and Pb (Anteojitos, Ojo de Agua de Solano). Additionally for the well Santo Domingo all the determined actinides and lantanides were significantly increased compared to the other wells (1-2 decades).

To ensure about this a second sampling serie for ICP-MS was taken in October. Unfortunately this time only Cr, Mn, Ni, Co, Zn, Cu, As, Se, Cd, Sb, Tl, Pb, Th and U were determined. Generally most concentrations were lower, sometimes even 1 to 2 decades (App.No.24d-f). The uranium peaks couldn´t be reproduced (2.64-15.23 µg/L) neither the Mn peak in P12 (1.17 µg/L) or the other significantly increased concentrations mentioned above. Li, B, Al, Sc and Ce concentrations couldn´t be checked since they were not determined, neither were the rare earth elements, thus the anomality in well Santo Domingo is neither proved. For further checking parallel sampled bottles of the first campaign were send to another laboratory (ACTLAB, Canada). However results are not yet available.

Since the October ICP-MS results were obtained just before finishing this work and less elements were determined, the results from June/July 1999 were used for cluster and correlation analysis since the concentration ratios between the groups were more or less reproduced with the second sampling serie. In the interpretation thus the lower concentrations from the second ICP-MS determination were considered and caution was used with single increased concentrations from June/July. This procedure was not really appreciated but the only way to handle the situation.

3.3.2.1.5 Pesticides

For the determination of organo-phosphate and organo-chloride pesticides water samples were enriched in the field via solid phase extraction (Fig.33), followed by GC-MS determination in the laboratory at the university in Freiberg. For detailed description of the application see App.No.6. Since the detection limit of the mobile GC-MS (gas chromatography with mass spectrometry detection) was too high the samples were analyzed a second time for chlorinated hydrocarbons by GC-ECD (gas chromatography with electron capture detector) with the disadvantage that the distinction of various pesticides is only possible from retention time, making the classification of detected peaks to certain pesticides more unsure.

Fig. 33 Pesticides´ enrichment in the field

Thus a third determination on selected samples was done with a GC-MS with lower detection limit from the laboratory of the Biologische Bundesanstalt für Land- und Forstwirtschaft Berlin-Dahlem (Prof. Dr. W. Pestemer) to ensure about the determined DDT-, DDD- and HCH peaks. To get quantitative results the area below each classified peak had to be determined and compared with the corresponding peak areas of the standard solution. Furthermore the obtained results had to be reduced by factor of the field enrichment in order to get the pesticide concentrations in the wells (ng/L range) (App.No.26).

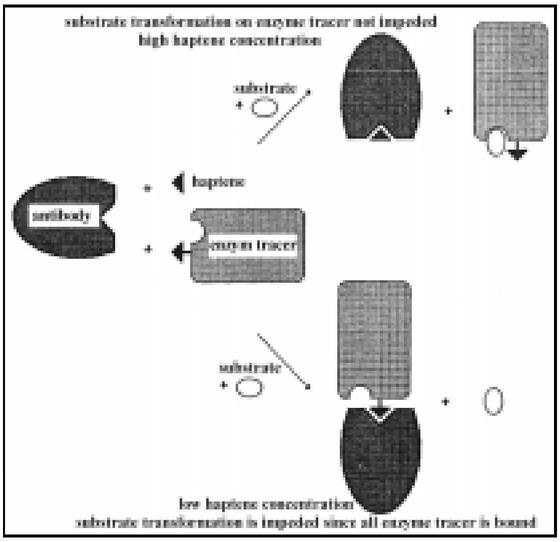
Phosphorous hydrocarbons were also analyzed but only qualitatively when this work was finished.

Deionized water that was kept as reference sample through the whole procedure from the very beginning (enrichment) turned out to be clear of pesticides except a hugh HCB peak, detected with GC-ECD and confirmed with GC-MS. Strangely enough this peak only occured in the deionized water, but in no well sample. Therefore contamination sources could either be in the production of the deionized water in the laboratory or could have happened to the deionized water during the field trip. Anyway since there were no increased HCB concentrations in the samples this presented no further problem.

Besides since there was the suspicion that especially DDT could have been used widely in the past this was examined with an ELISA (enzyme linked immuno sorbent assey) test kit in the field. The advantage of immunoassays are reasonable costs, simple practicability, quick results and in most cases a low detection limit The principle of this serological determination method is the pesticide adsorbtion on prepared antibodies. Pesticides are low molecular compounds, named haptenes (H), that are sorbed on antibodies (Ab) but can´t cause an own antibody production, in contrast to the higher molecular compounds, the antigens, that evoke the production of antibodies.

The mass action equation $H + Ab = HAb$ with $K = [HAb] / ([H]*[Ab])$ [l/mol] describes the chemical reaction. With a constant affinity K and a constant antibody concentration Ab the total haptene concentration determines the ratio HAb/H. Since this ration is not measurable in practice immunoassays contain additionally to the natural haptene a marked haptene (tracer, haptene-enzyme conjugate) that works in competition with the natural haptene for antibody binding sites. Therefore it is required that the number of antibody binding sites is limited, the antibodies have a high titer (= relative Ab concentration in the antiserum) and be sufficiently specific..

Two kind of tests are distinguished: homogeneous and heterogeneous tests. In homogeneous tests with no phase separation the more haptene the sample contains, the lower the part of tracer on binding sites will be. The added substrate can easily react with the free haptene-enzyme conjugate, the enzyme activity is high, directly proportional to the haptene concentration (Fig.34 above). In heterogeneous tests free and bound ligands are separated, like e.g. in the applied ELISAs. Antibodies are bound on a solid phase like the bottom surface of the prepared small one-way plastic columns. Added substrate can only react with bound tracer, so the more haptenes occupy antibody binding sites, the lower the enzyme activity will be indirectly proportional to the haptene concentration (Fig.34 right) (HOCK 1989). Heterogeneous tests have the advantage that even colored solutions (e.g. dull water) does not interfere with the ELISA.



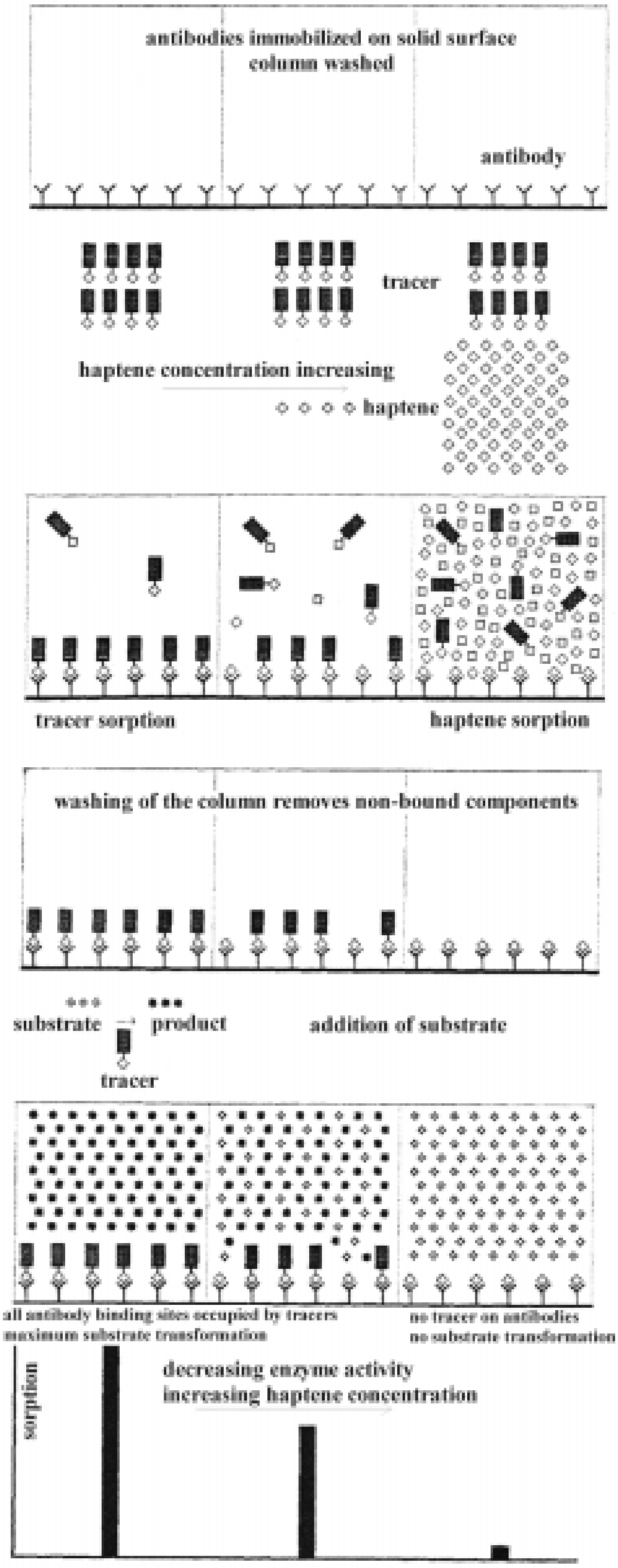


Fig. 34 Homogeneous ELISA (above) and heterogeneous ELISA (right) (HOCK 1989)

The exact application of the applied test kit can be seen in App.No.6. Unfortunately the lower limit of detection of the DDT-ELISA used is reported to be 0.04 ppm for p,p´-DDT, 0.01 ppm for p, p´-DDD, 0.4 ppm for o,p´-DDD and 4 ppm for o,p´-DDT, since this DDT-ELISA was mainly designed for soil analysis (extraction step resulting in higher concentrations). Thus the detected DDT-concentrations were close to the detection limit and therefore not very reliable (2 to 3 orders higher than the GC-ECD results) (App.No.25). Therefore for further interpretation only the results from GC-MS and GC-ECD were used (App.No.26).

3.3.2.2. Arsenic determination method - theoretical background

For determining arsenic in-situ a new method developed at the Freiberg University of Mining and Technology was applied eliminating the disadvantage of determination uncertainties due to duration and kind of sample storage. In this way it was possible to measure not only total arsenic but also As(III) and calculate from this As(V). This speciation is important for calculating a risk potential because the mobility and toxicology of As(III) is much higher than that of As(V). Since it was the first field operation for the equipment comparative measurements for total As were conducted with the hydride generation atomic sorption spectrometry (HGAAS) determination technique in Dra. M.A. Armienta´s laboratory in Mexico City.

As with many quantitative arsenic determinations like HGAAS or chromatography hyphenated with spectrometric determination the principle of this method is based on arsine (AsH_3) generation according to the principle Marsh detected in 1863. In general zinc and sulfuric acid transform elemental arsenic to gaseous arsine (AsH_3). Tin chloride solution is used to reduce As(V) and As(III) to As(0). The reaction is accelerated by adding potassium iodide as a catalyst for the main reducing agent tin chloride and copper sulfate solution to improve the zinc solution as a local element because Cu is nobler than Zn, so Zn dissolves. Compared to HGAAS though the arsine generation is much slower, impeding speciation. Silver diethyldithiocarbamate in pyridine sorbs the arsine producing a color reaction measurable with the spectrophotometer. The point for an in-situ-measuring device is a simple determination procedure with a small-scale equipment and a portable spectrophotometer (VOLKE & MERKEL 1997).

Fig.35 shows the equipment. For the determination of total arsenic 20 ml of water sample are filled in a brown 40-ml EPA vial. After adding 0.6 ml potassium iodide solution, approximately 1.5 g zinc granulate and 2 drops copper sulfate the vial is closed by a septum and a screw cap and placed into one of 5 sites in a special piacryle bloc. 2 ml reducing agent (tin chloride and sulfuric acid solution) are added with a syringe by pricking the septum. The remaining small hole in the septum is closed immediately with a needle.

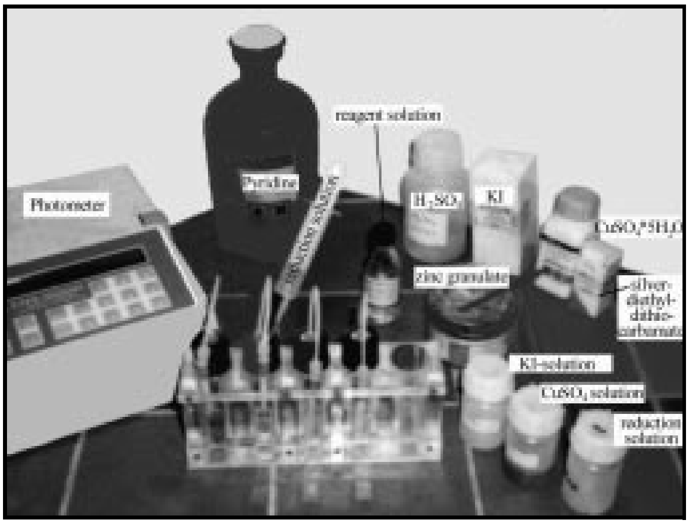


Fig. 35 Arsenic equipment

The developing arsine in the vial passes through a small plastic tube connected on one end to the septum, on the other leading into a pipette filled with approximately 150 mg lead acetate wad to prevent moisture moving from the vial dulling the pyridine solution. Right after adding the reducing agent the pipette tip is dipped into a 1-cm cuvet filled with 1.7 ml solution of pyridine and silver diethyldithiocarbamate fixed in one of 5 smaller sites in the piacryle bloc in front of the vials. A second injection of 2 ml reducing agent is necessary after about 20-25 minutes. After a reaction time of 45 minutes the solution in this cuvet (redish in the presence of arsenic) is analyzed in the spectrophotometer at a wavelength of 525nm against pure pyridine. The sorption of the pure pyridine in every cuvet has to be determined before the arsine input and will be subtracted from all the final sorption values (VOLKE & MERKEL 1997). With the help of a calibration function concentrations can be calculated from these extinction values (Fig.36).

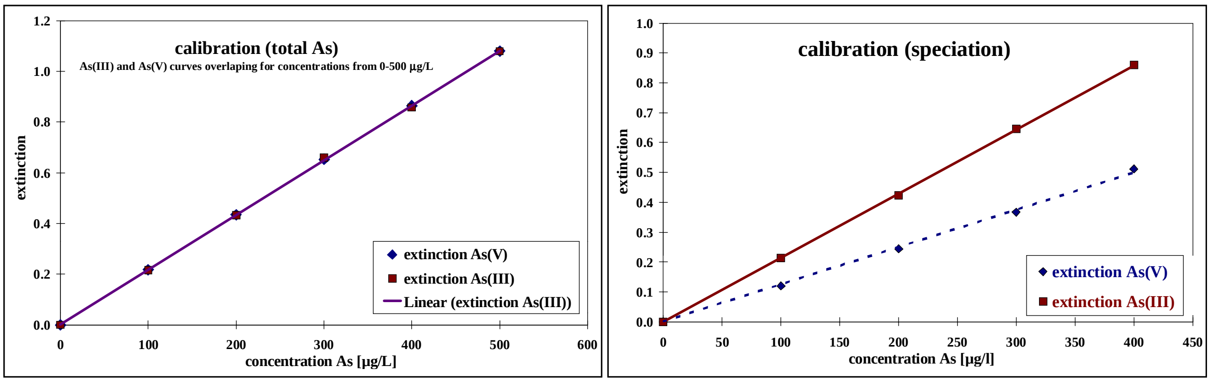


Fig. 36 Calibration lines for total arsenic determination and speciation (VOLKE & MERKEL 1997)

For speciation the amount of As(III) is determined and As(V) is calculated as the difference of As(total)-As(III). While potassium iodide is used for the determination of total arsenic as catalyst for the main reducing agents ZnCl and $CuSO_4$ it is not added for speciation determination. This slows down the reduction from As(V) to As(III), but also the following reduction from As(III) to As(0), that is needed for the AsH_3 generation.

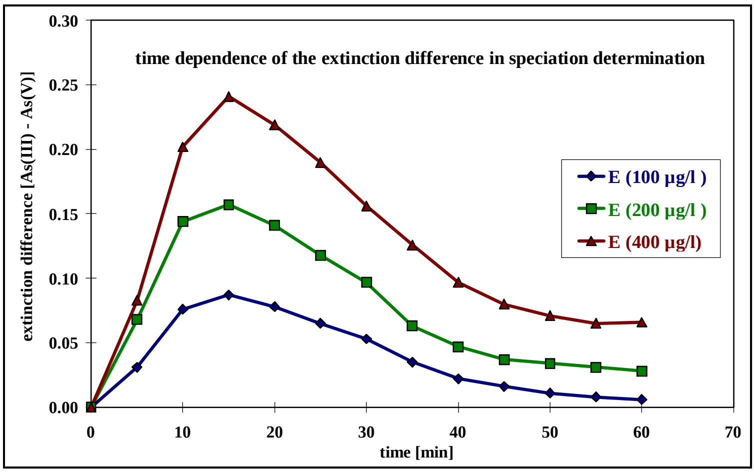


Fig. 37 Time dependence of the extinction difference in speciation determination (VOLKE & MERKEL 1999)

Since it is never possible to determine pure As(III) in a natural water sample, because some As(V) will always be reduced, it is necessary to consider the reaction kinetics in order to obtain the time at which enough As(III) is transformed to AsH_3 for quantitative determination, but yet not too much As(V) is reduced and determined as "by-product" with As(III). Fig.37 shows an experiment with different standard solutions for which this maximum extinction difference between As(III) and As(V) appears after 15 minutes. This time was applied very exactly for all conducted speciation determinations. The second addition of reducing agent that is applied after 20-25 minutes in the determination procedure for total arsenic is skipped for speciation (VOLKE & MERKEL 1997).

For the calculation of the As(III) concentration from the extinction value the share of As(V) that is determined with As(III) has to be considered. The following equation is used in VOLKE (1997):

$$c_{As(III)} = (E_{ges.spez} - c_{ges.} * e_{As\,(V)}) / (e_{As\,(III)} - e_{As\,(V)}) \qquad Eq. (1)$$
$$c_{As(V)} = c_{ges.} - c_{As(III)} \qquad Eq. (2)$$

with: b = slope of the calibration line
e = 1/b = extinction coefficient
c = concentration
E = extinction

The extinction obtained from the speciation determination is $E_{ges.spez}$, considering both the "target substance" As(III) and the share of As(V) that is determined as "by-product". The extinction coefficients for As(V) and As(III) have to be determined from calibration lines, c_{ges} is the concentration of total arsenic. For critical statement and further explication of Eq.1 see chapter 5.2.3.2.2.

In general the chemicals necessary for this determination (Fig.38) correspond to DIN EN 26595 (1992), the necessity and amount of each chemical, the volume of the reagent solution, the reaction time and the special demands for the determination of As(III) were tested and improved to obtain adequate concentrations for this small-scale determination (VOLKE & MERKEL 1997). Fig.39 shows the arsine generation under varying conditions for As(III) and As(V). It is obvious that maximum extinction is obtained with the above mentioned kind and amount of chemicals (curve A) and the reaction time of 45 minutes. Especially without $SnCl_2$ (curves B and D) the resulting extinction is too low for quantitative analysis. Skipping the use of KI (curve D) makes almost no difference for As(V) but presents lower extinction values for As(III); the speciation determination is based on this phenomenon.

Necessary solutions for arsenic determination

reagent solution
0,2g silver diethyldithiocarbamate MERCK have to be diluted in 40ml pyridine (50ml glas bottle) - in a dark, cool environment the solution will keep several weeks

potassium iodide solution
7,5g KI suprapur MERCK have to be diluted in deionized water and filled to 50ml in a plastic bottle - the solution must be colorless, yellow color indicates aging. Do not use anymore!

copper sulfate solution
7,5g $CuSO_4 * 5H_2O$ have to be diluted in deionized water and filled to 50ml in a plastic bottle - the solution can be kept for months

zinc granulate solution
grain size 0.3 to 1.5mm (for reductors) MERCK

tin chloride solution
25g $SnCl_2 * 2H_2O$ MERCK have to be diluted in 25ml HCl suprapur MERCK (1:1 diluted) and filled with deionized water to 50ml in a plastic bottle

reduction solution
40ml sulfuric acid (1:1 diluted) and 2ml tin chloride have to be mixed - the solution normally can´t be kept more than a few days, smell of sulfur hydrogen indicates aging. Do not use anymore!

lead acetate for lead acetate wad
25g lead acetate have to be diluted in 250ml H_2O, the wad has to be watered with this solution, the remaining solution removed with funnel, succion bottle and pump, then the wad is dried in the oven at 100°C; 150mg of wad has to be filled in each pipette with a pair of tweezers.

original calibration solution (500mgAs/l)
Arsenite:86,7mg Sodium Metaarsenite purum FLUKA dilute to 100ml
Arsenate: 208,7mg Disodiumhydrogenarsenate-Heptahydrat puriss. FLUKA diluted to 100ml

Fig. 38 Solutions necessary for the arsenic field determination

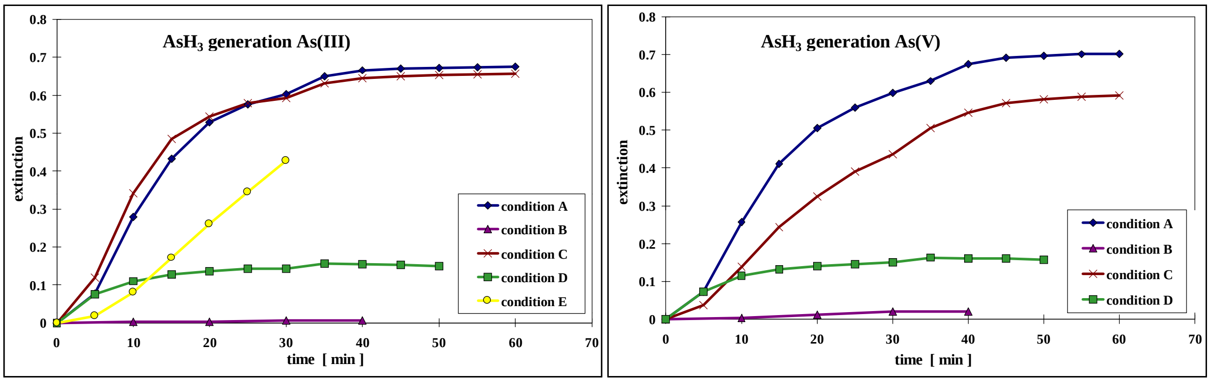


*Fig. 39 Generation of AsH_3 under varying conditions for As(III) and As(V) solutions (**A** = addition of KI, Zn, $CuSO_4$ and H_2SO_4/$SnCl_2$, **B** = addition of KI, Zn, $CuSO_4$ and H_2SO_4, **C** = addition of Zn,$CuSO_4$ and H_2SO_4 /$SnCl_2$, **D** = addition of Zn, $CuSO_4$ and H_2SO_4, **E** = addition of KI, Zn and H_2SO_4/$SnCl_2$)*

The determination uncertainties for total arsenic determination are reported to be ±6% for calibration with As(III) and ±8% for calibration with As(V), a little bit higher probably due to the additional reduction step. Anyway there are no significant differences in the calibration with As(III) and As(V), so one calibration function is enough for the determination of total arsenic. For speciation single errors multiply from different quantities so the total error is ±17% (VOLKE & MERKEL 1997).

The upper detection limit of this method is reported to be 500 µg/L, above this concentration sorbances vary and are still increasing after the normal 45 minutes, therefore dilution is recommended for higher concentrations. The lower detection limit is described to be 5 µg/L according to the 3σ criterion (VOLKE & MERKEL 1997).

3.3.3. Interpretation of the chemical analysis

3.3.3.1. Statistics & characterization

For interpreting the chemical analysis the examined wells and springs were divided in groups with similar chemistry by cluster analysis. The entire cluster analysis as shown in Tab. 7 was conducted only with the results for the main ions from the first sampling in June/July 1999 with the program *S-PLUS* (method K-means) (App.No.7, App.No.8). Only variables that were determined in all samples (temperature, pH, conductivity, CO_2, HCO_3, K, Na, Mg, Ca, Cl, SO_4, SiO_2, F, NO_3, As) were taken into account for the calculation in order not to deal with the missing-values-problem. The resulting matrix for the June/July samples contained 30 cases with 15 variables.

To check for significant differences between the calculated clusters a one-factor variogram analysis was done with the program *Joker* (method ANOVA) (App.No.7). As output value the harmonic mean was prefered to the arithmetic mean since it considers that different subgroup sizes are not the result of real conditions (arithmetic mean) but just an effect of sampling, e.g. the El Refugio subgroup contains only 14 sampled wells while there are about 600 wells in the area (ratio 1:43), for the Pastora subgroup the ratio maybe about 1:1, whereas from the subgroup springs all important locations were sampled.

The harmonic mean is related to a probability of error and is further refered to as "significancy" , e.g. 0.0001 means that for 99.99% the assumed hypothesis is correct and there is only a risk of 0.01% for the hypothesis being false. A significancy of 0.05 (5%) is regarded as acceptable with a security of 95% for making the right decision. The significancy is referred to as "better" or "higher" when the output value is lower and vice versa e.g. 0.0001 is more significant than 0.1.

Tab. 7 Entire cluster analysis (clusters from 2 to 30) calculated with the results from 30 wells and springs from June-July 1999 (App.No.24) considering temperature, pH, conductivity, CO_2, HCO_3, K, Na, Mg, Ca, Cl, SO_4, SiO_2, F, NO_3, As; 30 cases with 15 variables, program: SPLUS, method: K-means

	El REFUGIO												spring	El Refugio	SPRINGS							PASTORA								
name	P3	P16	P9	PSD	P17	El Encinito II	Huerta los Pinos	Chilera	El Peloateado	El Encinito I	P12	Las Guayabas	Ojo de Agua de Solano	Dona Matilde	Anteojitos	Media Luna F	Media Luna E	Media Luna cave	Media Luna D	Media Luna B/C	Media Luna A	Chamizal	Vergel II	Santo Domingo	San Isidro	La Gloria	Rancho 13	Vergel I	Pastora	La Cabana
	1	2	3	4	5	6	7	8	9	10	11	12	30	13	23	24	25	26	27	28	29	14	15	16	17	18	19	20	21	22
number of clusters																														
2	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 23, 24, 25, 26, 27, 28, 29, 30																					14, 15, 16, 17, 18, 19, 20, 21, 22								
3	1, 2, 3, 4, 5, 6, 7							8, 9, 10, 11, 12, 13, 23, 24, 25, 26, 27, 28, 29, 30, 14															15, 16, 17, 18, 19, 20, 21, 22							
4	1, 2, 3, 4, 5, 6, 7							8, 9, 10, 11, 12, 13, 23, 24, 25, 26, 27, 28, 29, 30														14, 15, 16, 17, 18					19, 20, 21, 22			
5	1, 2, 3, 4, 5, 6, 7							8, 9, 10, 11, 12, 13, 23, 24, 25, 26, 27, 28, 29, 30														14	15, 16, 17, 18				19, 20, 21, 22			
6	1, 2, 3, 4, 5, 6						7, 8, 9			10, 11, 12, 13, 23, 24, 25, 26, 27, 28, 29, 30												14	15, 16, 17, 18				19, 20, 21, 22			
7	1, 2, 3, 4, 5, 6						7, 8, 9			10, 11, 12, 13, 23, 24, 25, 26, 27, 28, 29, 30												14	15, 16, 17, 18				19, 20		21, 22	
8	1, 2, 3, 4, 5					6, 7		8, 9		10, 11, 12, 13, 23, 24, 25, 26, 27, 28, 29, 30												14	15, 16, 17, 18				19, 20		21, 22	
9	1, 2, 3, 4, 5					6, 7		8, 9		10, 11, 12, 13, 23, 24, 25, 26, 27, 28, 29, 30												14	15, 16, 17, 18				19, 20		21	22
10	1, 2, 3, 4, 5					6, 7		8, 9		10, 11, 12, 30				13, 23, 24, 25, 26, 27, 28, 29								14	15, 16, 17, 18				19, 20		21	22
11	1, 2, 3, 4, 5					6, 7		8, 9		10, 11, 12, 30				13, 23, 24, 25, 26, 27, 28, 29								14	15, 16, 17, 18				19	20	21	22
12	1, 2		3, 4, 5			6, 7		8, 9		10, 11, 12, 30				13, 23, 24, 25, 26, 27, 28, 29								14	15, 16, 17, 18				19	20	21	22
13	1, 2		3, 4, 5			6, 7		8, 9		10, 11, 12, 30				13, 23, 24, 25, 26, 27, 28, 29								14	15, 16		17, 18		19	20	21	22
14	1, 2		3, 4, 5			6, 7		8, 9		10, 11, 12, 30				13, 23, 24, 25, 26, 27, 28, 29								14	15	16	17, 18		19	20	21	22
15	1, 2		3, 4, 5			6	7	8, 9		10, 11, 12, 30				13, 23, 24, 25, 26, 27, 28, 29								14	15	16	17, 18		19	20	21	22
16	1, 2		3, 4, 5			6	7	8, 9		10, 11, 12, 30				13, 23, 24, 25, 26, 27, 28, 29								14	15	16	17	18	19	20	21	22
17	1, 2		3, 4, 5			6	7	8, 9		10, 11, 12, 30				13, 23, 24, 25				26, 27, 28, 29				14	15	16	17	18	19	20	21	22
18	1, 2		3, 4, 5			6	7	8, 9		10, 11, 12, 30				13	23, 24		25, 26, 27, 28, 29					14	15	16	17	18	19	20	21	22
19	1, 2		3, 4, 5			6	7	8	9	10, 11, 12, 30				13	23, 24		25, 26, 27, 28, 29					14	15	16	17	18	19	20	21	22
20	1, 2		3, 4, 5			6	7	8	9	10, 11		12, 30		13	23, 24		25, 26, 27, 28, 29					14	15	16	17	18	19	20	21	22
21	1, 2		3, 4, 5			6	7	8	9	10, 11		12, 30		13	23, 24		25, 26, 27, 28				29	14	15	16	17	18	19	20	21	22
22	1, 2		3, 4		5	6	7	8	9	10, 11		12, 30		13	23, 24		25, 26, 27, 28				29	14	15	16	17	18	19	20	21	22
23	1	2	3, 4		5	6	7	8	9	10, 11		12, 30		13	23, 24		25, 26, 27, 28				29	14	15	16	17	18	19	20	21	22
24	1	2	3, 4		5	6	7	8	9	10, 11		12, 30		13	23	24, 25		26, 27, 28			29	14	15	16	17	18	19	20	21	22
25	1	2	3, 4		5	6	7	8	9	10, 11		12	30	13	23	24, 25		26, 27, 28			29	14	15	16	17	18	19	20	21	22
26	1	2	3	4	5	6	7	8	9	10, 11		12	30	13	23	24, 25		26, 27, 28			29	14	15	16	17	18	19	20	21	22
27	1	2	3	4	5	6	7	8	9	10	11	12	30	13	23	24, 25		26, 27, 28			29	14	15	16	17	18	19	20	21	22
28	1	2	3	4	5	6	7	8	9	10	11	12	30	13	23	24	25	26, 27, 28			29	14	15	16	17	18	19	20	21	22
29	1	2	3	4	5	6	7	8	9	10	11	12	30	13	23	24	25	26	27, 28		29	14	15	16	17	18	19	20	21	22
30	1	2	3	4	5	6	7	8	9	10	11	12	30	13	23	24	25	26	27	28	29	14	15	16	17	18	19	20	21	22

The significancy test was only conducted for the 2 to 10-cluster models since a subdivison of only 30 cases in more than 10 groups is useless (App.No.9). All cluster models show very significant differences of >0.05% ("<0.0005") for the variables conductivity, HCO_3, K, Na, Mg, Ca, SO_4, F and Cl (except for "only" 0.1% for 4- and 5-clusters, 0.6% for 3 clusters). NO_3 is not significant in any cluster model but is neither regarded as a grouping variable for similar *natural* origins, just as little as the pH value due to only slight differences in all samples (pH 6.73 to 7.19).

Considering the basin´s geology water temperature should be a significant parameter since there is a shallow Quarternary aquifer regularly recharged by precipitation in the basin, a deeper Cretaceous aquifer probably already influenced by the geothermal gradient and maybe lateral flows from the karst springs being in exchange with outside temperature. Therefore the cluster models with a significancy worse than 5% for the variable temperature (models 5 to 10) were rejected. From the remaining models (2, 3 and 4) 3 and 4 were put on the shortlist due to better significancies for CO_2 and SiO_2 with the disadvantage of worse signifancies for As.

To get further confirmation on the cluster memberships a second cluster analysis was done for 2 to 6 clusters with the results for the main ions from October 1999 (App.No.10) with two variable configurations (VC):

- (1) the same variables like in in the June/July cluster analysis except for As, which was not determined the second time (VC 1)
- (2) the same variables plus E_H, oxygen, NO_2, PO_4 and Li, which were determined the second time completely (VC2).

The entire matrix contained 24 cases with 14, respectively 19 variables. The wells La Gloria, San Isidro and La Cabana couldn´t be examined the second time; from the spring Media Luna only a mixed sample was taken instead of the sampling from the different outlets Media Luna A-F and Media Luna cave. The drinking water well PSM and the spring Charco Azul were examined additionally only the second time. PSM joins with the other drinking water wells P3, P9, P16, P17, PSD as well as El Encinito I and Huerta los Pinos, the spring Charco Azul with the other springs Media Luna, Anteojitos and the well Dona Matilde.

The resulting clusters from the October 1999 sampling are identical for VC1 and VC2 and similar to the ones from June/July results. Minor differences occure within the Pastora subgroup (for the 3-cluster model the well Chamizal (subgroup Pastora) is grouped with the other Pastora wells and for the 3, 4, 5 and 6-cluster model the well Pastora (subgroup Pastora) with the Chamizal-VergelII-Santo Domingo-subgroup instead of the Rancho#13-Vergel I subgroup). Remarkably is the subdivison of the Pastora samples in the 3-cluster model while El Refugio and spring samples still join one group. In the 6-cluster model the 3-cases-subgroup is El EncinitoII-Huerta los Pinos-Chilera instead of Huerta los Pinos - Chilera-El Peloteado.

App.No.11 pictures that the signifcancies for temperature and SiO_2 generally are too low considering the hydrogeological idea mentioned above. The variables that were measured additionally only with the October samples (VC2) show poor significancy. The better significancy for the variable pH compared to the June/July clusters seems to be an artefact.

The clusters calculated from the determined isotopes (20 cases (El Encinito I, El Encinito II, Huerta los Pinos, Las Guayabas, Dona Matilde, Media Luna crater A, Media Luna crater D, Media Luna crater E, Chamizal and La Gloria were not sampled) with 3 variables [tritium (^3H), deuterium (^2H), oxygen (^{18}O)]) show an incomprehensible different grouping than all the other cluster analysis except for the 2-cluster model (App.No.12). While the significancies for deuterium and Oyxgen (18) are excellent in any model there is no significant distinction on the variable tritium; maybe this is owed to the generally low tritium concentrations (App.No.13).

Unfortunately it was not possible to check the significancy of the cluster membership with the entire July ICP-MS data, since with 21 cases (El Encinito II, Huerta los Pinos, Las Guayabas, Dona Matilde, Media Luna crater A, Media Luna crater D, Media Luna crater E, Chamizal and La Gloria were not sampled) and 36 variables the system was underdetermined. Therefore variables were selected according to considerable absolute concentrations, coming up with 21 cases and 19 variables (Li, B, Al, Mn, Fe, Cr, Co, Ni, Cu, Zn, As, Se, Sr, Ba, Sc, Tl, Pb, Th, U) (App.No.14).

In principle the clusters are the same like the ones from June/July, some differences occure again in the Pastora subgroup (well Vergel I and Pastora group with the VergelII-San Isidro-Santo Domingo group instead of the Rancho#13-La Cabana group). Interesting is the subdivision of the springs and wells in the El EncinitoI-Chilera-El Peloteado-P12-Ojo de Agua de Solano-Anteojitos-Media Luna group which doesn´t occure in any other cluster model.

In all cluster models there is a significant distinction between the groups concerning the variables Li, B, Ni, As, Se, Sr and Ba, additionally Co (3- and 6-clusters), Sc (5- and 6-clusters), Tl (2- to 4-clusters) and U (4- to 6-clusters) (App.No.15). Other elements show worse significancy, acceptable e.g. for Fe and Zn since these elements often reflect just local effects of the well equipment (zinc pipes, rusted pipes).

Summarizing all the above mentioned single cluster analysis and comparing the cluster membership manually with the results of the chemical analysis an ultimate clustering was tested for the main ions, isotopes and ICP analysis containing 4 groups:

- **(1)** P3, P9, P16, P17, PSD, PSM, El Encinito II, Huerta los Pinos
- **(2)** Las Guayabas, Chilera, El Encinito I, El Peloteado, P12, Dona Matilde (separated from (3) like in the ICP clustering since they represent a "transition" group between (1) and (3) not only for heavy metals but also for the main ions and the isotopes)
- **(3)** Media Luna, Anteojitos, Ojo de Agua de Solano, Charco Azul
- **(4)** La Cabana, Pastora, Chamizal, San Isidro, Santo Domingo, Vergel I, Vergel II, Rancho#13, La Gloria (all samples from the Pastora area combined in one group contrary to the suggestions off the cluster analysis since the distinction of the whole group to the groups 1-3 is very clear but an internal separation is not only varying with the variables but also with the sampling dates)

The significancies for this clustering are indicated as the last rows (*4cluster*) in each significancy table of the single variable-groups. The significancies for the main ions June/July (App.No.9) are excellent, the only variable of less significancy is arsenic (12%). The additional variables analyzed only for the main ions in October (App.No.11) are still insignificant except for E_H (3.9%). Temperature significancy that was unsatisfactory with all the other models before has considerably increased with the new *4-cluster* model (0.9%). SiO_2 is still insignificant like in all the other models (contrary to the June/July samples). For isotopes significancies decreased a little bit but are still significant for ^2H (2.6%) and ^{18}O (3.9%), tritium remains insignificant as group variable (App.No.13). For the ICP there is a deterioration for Tl and U, but an improvement for Al (4.1%), Co (2%), Cu (2.5%) and Sc (0.1%) (App.No.15). Summarizing the above mentioned 4-cluster model (*4 cluster*) seems to supply the best fit for the combination of all variables.

Thus the aquatic chemistry was interpreted in the above described groups (1) to (4) (chapter 5.2.1). To visualize the cluster membership Piper and Stiff diagrams were plotted for the main ions with the program RockWorks99. The analytical data of 4 samples had to be corrected since the ion balance errors exceeded 6%, calculated with the formula [(Σcations-Σanions) / (Σcations+Σanions)] * 100 (App.No.16). The correction was done by increasing or decreasing the concentration of the ion with the highest original concentrations (sulfate) in order to affect the original numbers as little as possible.

In order to characterize the groups according to their mean composition minimum, maximum, mean values and standard deviation for each group were calculated (App.No.27, App.No.28) and a correlation analysis was conducted with the program *Joker* for the June/July 1999 samples (App.No.31). Spearman correlation was prefered to Pearson correlation since normal distribution of the variables seems unlikely. Saturation indices and speciation were calculated for the June/July samples with *PhreeqC2* (App.No.7, App.No.32).

Especially for the rare earth elements but also for some other elements locally increased concentrations within a group were specially mentioned. The respective concentrations for each element in the 4 groups were compared with natural background values and limitations concerning the water use based on App.No.36.

3.3.3.2. Simulation of origin of water type

For simulating the origin of the different water types silicium concentrations were used to get an idea of the circulation depth (SiO_2-geothermometer) and stabile isotopes to make estimations about the recharge area of the different water types. After developing a model combining the hydrogeological settings with the results from hydrogeochemical investigations, the geochemical modeling program *PhreeqC2* was applied to check if the supposed development can be simulated with inverse modeling.

3.3.3.2.1 Inverse modeling with PhreeqC

As starting solution an average low mineralized precipitation (analysis from GRANAT 1976 for northern Europe) was taken, since no analysis from the area itself existed. The analysis from P9, Chilera, Media Luna and Pastora were taken as representatives for each group, only pH, the main ions Na, K, Ca, Mg, SO_4, Cl, HCO_3 and SiO_2 were considered. Differences between the low mineralized precipitation and the higher mineralized groundwater analysis are supposed to result from reactions between water and minerals which have to be selected according to the pre-knowledge from geology. The objective of inverse modeling is then to find (a) set(s) of minerals that, when reacted in appropriate amounts, quantitatively account for the differences in composition between the input solutions.

Since minor and rare elements as well as factors like reaction kinetics, oxidation or concentration through evaporation were not considered at all, this modeling can only be a first approximation confirming the general idea of geology, hydrology and hydrogeochemistry.

3.3.3.2.2 Stabile isotopes

The stabile isotopes deuterium (^{2}H) and Oyxgen (^{18}O) were determined by the BGR, Hannover (Prof. Dr. M. Geyh). For interpreting these groundwater analysis (App.No.24) a $\delta^{18}O$-$\delta^{2}H$-diagram was calculated with the groundwater samples and the global meteoric water line as a reference for their provenance (Fig.110). The global meteoric water line (MWL; modified CRAIG line) is calculated from precipitations as a world wide average of varying climates and geographic situations (ROZANSKI et al. 1993):

$$\boldsymbol{\delta^{2}H = 8.17\ (\pm 0.07) * \delta^{18}O + 11.27\ (\pm 0.65)\ ‰\ SMOW} \qquad \textit{Eq. (3)}$$

SMOW = standard mean ocean water

For detailed isotopic studies samples would have to be taken in time series over at least one or two years in order to eliminate seasonal effects and a local MWL would be necessary taking into consideration all individual parameters like exact latitude, altitude, origin of vapor masses, secondary evaporation during rainfall, seasonality of precipitation, etc. Due to the limited amount of time to spend on field work and limited funds the comparison of the few samples analyzed with the global MWL must be sufficient.

Two factors are used for the hydrogeological interpretation: The plotting of the samples **along** the Craig line and their distance **from** it in the $\delta^{18}O$-$\delta^{2}H$-diagram.

The location of the samples along the Craig line is used to characterize groundwater recharge environments. Since isotope partitioning strongly correlates with temperature the composition of the groundwater depends on seasonal variations, altitude, latitude, continentality or palaeoclimates. Generally rainout from supersaturated vapor starts due to slight cooling (maybe combined with increasing altitude) with a precipitation strongly enriched in the heavy isotopes ^{2}H and ^{18}O leaving the remaining vapor depleted. Subsequent rain in progressively colder environment is still enriched in isotopes compared to the vapor but depleted compared to the initial rain. Therefore for the reconstruction of groundwater recharge areas the approximation is made that $\delta^{18}O$ concentration decreases by 2 ‰ with an increase of 1000 m altitude.

As an approximation for mean $\delta^{18}O$ values at sea level -5 ‰ was choosen for Mexico according to Fig.40.

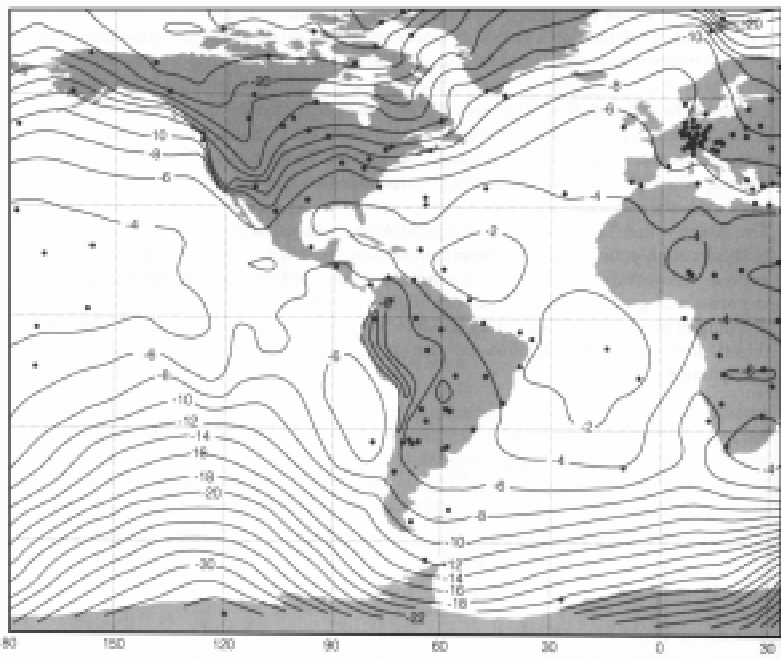


Fig. 40 Mean $\delta\ ^{18}O$ distribution in precipitation of the world (CLARK & FRITZ 1997)

The distance of the samples from the Craig line is used to detect evaporation effects in the groundwater after infiltration of the meteoric water. Compared to seawater the MWL is slightly displaced to the left. Under conditions of 100% humiditiy water vapour would be in isotopic equilibrium with seawater and the calculated line would just be $\delta\,^{2}H = 8.17 * \delta^{18}O$ identical with the seawater line. But since atmospheric water vapour forms under about 85% humidity there is this slight displacement of the line, leading to a deuterium excess of $\delta\,^{2}H = 8 * \delta^{18}O + \mathbf{d}$, with d = 11.27 ‰ for the modified Craig line (Eq.3).

Reversing this process, simulating a subsequent evaporation of the meteoric water and calculating the corresponding deuterium excess d_{exc} ($d_{exc} = \delta\,^{2}H - 8.17 * \delta^{18}O$) , this d_{exc} can be used as a scale for the effect of evaporation; the more it differs (negatively) from 10 ‰ the higher the evaporation effect was.

3.3.3.2.3 SiO_2-geothermometer

The use of SiO_2 as "geothermometer" is based on the fact that depending on temperature different SiO_2 modifications form: amorphous SiO_2 in very low, chalcedony in low-medium and quartz in high temperature range. With the information of the local geothermal gradient it is possible to calculate the depth of the water circulation, provided that there was enough time for the water-rock interactions to reach equilibrium at that depth and on contrary a considerable short time for the uplift of the water (no time for precipitation). Since unfortunately no data about the geothermal gradient of the area investigated were available, temperature increase with depth was estimated based on an average of 3°C / 100 m, respecitvely more for areas with young volcanism.

FOURNIER & POTTER (1982) present two equations to calculate the temperature of SiO_2 formation depending on the modification (quartz or chalcedony):

quartz: $T\,[°C] = (1309 / (5.19 - \log SiO_2)) - 273.15$
chalcedony: $T\,[°C] = (1032 / (4.69 - \log SiO_2)) - 273.15$

Generally the first equation was appplied since in most of the sampled wells quartz predominates as SiO_2 modification while chalcedony and especially amorphous SiO_2 and Silicagel are under-saturated. In samples where the water was in equilibrium with chalcedony or close to it ($SI < -0.06$) the second formula was used. The single records of saturation indices for quartz, respectively chalcedony and the calculated temperatures are presented in App.No.33. The results of the second sampling from the well Huerta los Pinos were not taken into consideration since the SiO_2 concentration seemed incredibly high with 122.5 mg/L, especially compared to the results from the first determination with 47.75 mg/L.

4. INTERPRETATION - GEOLOGY

Chapter 4 presents the geological results obtained during the field work in June/July and October 1999 and the consequent interpretations using existing geological maps, a DEM (digital elevation model) and a landsat satellite image from 1986.

4.1. Geological outcrops

A map of the geology of the study area sensu stricto (southern part of the basin) as well as the locations of the examined outcrops are part of the digital tntmips atlas [file geology, geological map respectively outcrops].

4.1.1. Cretaceous

The oldest rocks outcropping in the study area are marine limestones from the El Doctor formation (Middle Cretaceous). The darkgray, cryptocristalline rock forms several smaller hills in the basin like e.g. the ones south of Palomas, south of El Jabali (Fig.41 top) or south and west of La Reforma as well as the basin´s border to the northwest, north and east. The facies distinction reported by several authors (chapter 2.2.2.2.3) couldn´t be detected since the examined rocks didn´t show characteristic differences like fossils, oolithes, redish lutites or chert layers. This is probably owed to the fact that the easy accessible outcrops contained no fresh cuts but only massive weathered limestone blocs with secondary solution marks (Fig.41 left).

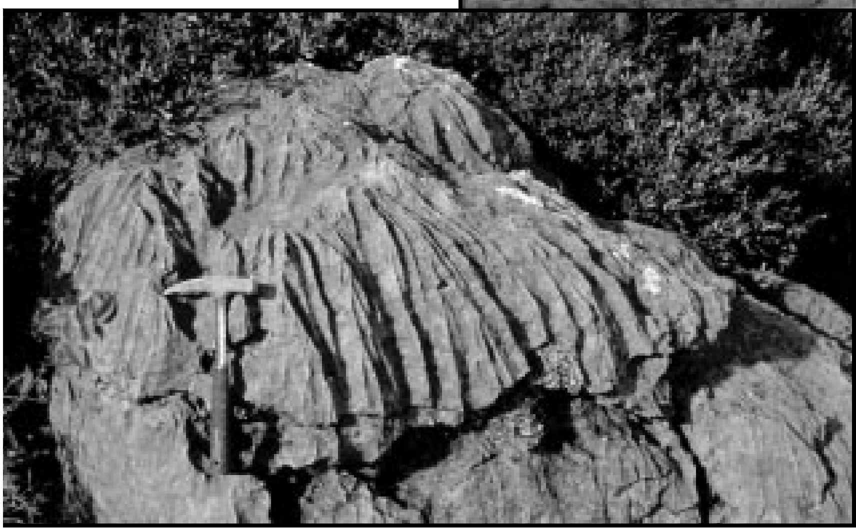


Fig. 41 El Doctor limestone hill outcrop #5 (top) and limestone bloc with solution marks outcrop #3 (left)

In outcrop #7a the Cretaceous limestone is mined (Fig.42 left). The darkgray massive rock shows a yellowish weathered cover, some calcite veins and in some parts of the quarry alterations of iron oxide. In the lowest part of the outcrop two types of conglomerates were found. The coarser conglomerate contains almost exclusively angular to slightly rounded El Doctor limestone components of 3-4cm, max. 10

cm in diameter, cemented with calcareous material (Fig.42 right). The matrix shows some black Manganese dendrites. The same conglomerate was found in outcrop #9.

Fig. 42 Quarry on Cretaceous limestone (outcrop #7a), right: coarse conglomerate with El Doctor components, bottom: finer conglomerate with rhyolith components

The finer conglomerate in outcrop #7a has mostly angular rhyolith components of less than 1 cm in diameter, besides some basalt and El Doctor limestone components, only weakly cemented with calcareous material (Fig.42 bottom). Outcrop #7b, an old quarry about 300 m further downhill, also shows this type of fine conglomerate.

Since all the El Doctor limestones from the different outcrops showed similar features one sample was taken arbitrarily from outcrop #13 for the simulated silicate weathering - extraction (ICP-MS) (chapter 3.1.1.1). Most of the trace elements are neglectibly low, remarkable are high uranium and slightly increased arsenic concentrations (App.No.17).

Tab. 8 Examined Cretaceous outcrops

#	name	latitude, longitude	description
1	Hill southwest of Palomas	N 21°50.519´, W 100°00.079´	El Doctor rocks
2	Hill west of Palomas	N 21°50.588´, W 100°00.778´	all around the hill El Doctor rocks, no real good outcrops
3	Hill west of Media Luna	N 21°51.598´, W 100°02.041´	El Doctor weathered blocs
4	Hill northeast of Aguacate	N 21°52.091´, W 100°04.134´	El Doctor rocks
5	Hill southwest of El Jabali	N 21°52.829´, W 100°03.433´	El Doctor weathered blocs
6	North of the road El Jabali-Aguacate	N 21°52.914´, W 100°03.592´	El Doctor rocks
7	Quarry on the hill El Chichote on the highway Rioverde-Ciudad Valles	a N 21°53.662´, W 099°52.198´	400x150m, 40-50m high, downslope two types of conglomerate (coarse one with El Doctor components of 3-4, max.10cm, fine one with rhyolith components <1cm)

#	name	latitude, longitude	description
7		b N 21°53.600´, W 099°52.448´	old quarry 200m further downslope 100x20m, about 5m high, fine conglomerate
8	Hill east of Ildefonso Turrubiates	a N 21°55.603´, W 099°51.992´ b N 21°55.495´, W 099°52.000´	El Doctor rocks, weathered blocs and rocks
9	Hill west of Puente Las Adjuntas on the highway SLP-RV	N 21°57.472´, W 100°04.591´	El Doctor rocks, downslope weakly cemented white-yellowish conglomerate with El Doctor components (2-3cm, max.10cm)
10	Hills south of Ojo de Agua de Solana on the highway SLP-RV	a N 21°57.486´, W 100°04.629´ b N 21°57.514´, W 100°04.914´ c N 21°58.081´, W 100°05.386´ d N 21°58.000´, W 100°05.271´	El Doctor rocks
11	Hill El Almagre	N 21°58.642´, W 099°52.450´	El Doctor rocks, layers cut rectangular by the hill slope
12	Hill west of Ojo de Agua de Solana	a N 21°58.648´, W 100°05.150´ b N 21°59.201´, W 100°05.283´	El Doctor rocks and weathered blocs
13	Hill Grande	N 22°01.093´, W 100°05.538´	El Doctor blocs, sample for simulated silicate-weathering extraction
14	Hill south-southeast of Diego Ruiz	a N 22°06.852´, W 100°09.435´ b N 22°06.989´, W 100°09.801´	El Doctor rocks

4.1.2. Tertiary

4.1.2.1. Volcanic rocks

Tertiary is mainly represented by volcanic rocks (predominantely rhyolithes) forming a large complex southwest of the basin (Fig.43) and several smaller ones on the basin´s eastern and northwestern margins. Besides rhyolith outcrops in the basin, e.g. on the hill El Jabali and on the hill east of San Diego dam (Fig.44).

The amount of quartz, characteristic mineral of the rhyolith, varies. In outcrop #21 the quartz crystalls are especially numerous and large (up to 5mm). Idiomorphous mineral shapes are rare, but some rocks from outcrop #19 show long rectangular, idiomorphous plagioclase.

Fig. 43 Outcrop #23 - rhyolith complex southwest of the Rioverde basin

The rhyolith´s color ranges from bleached pink, meat colored to darkred-brown and darkgray. In many outcrops the rhyolith is severly weathered, mafic minerals are replaced by iron oxides, in outcrop #19 the red alcaline feldspar is replaced by green clay minerals (probably serpentinite or chlorite). Fig.44 shows a darkred-brown rhyolith where the white feldspar grains are surrounded by zones of yellowish iron oxide. In outcrop #19 and #20 the rhyolith weathering only left redish-yellowish-white-brown sand with single rhyolith blocs mostly smaller than 1 cm in diameter.

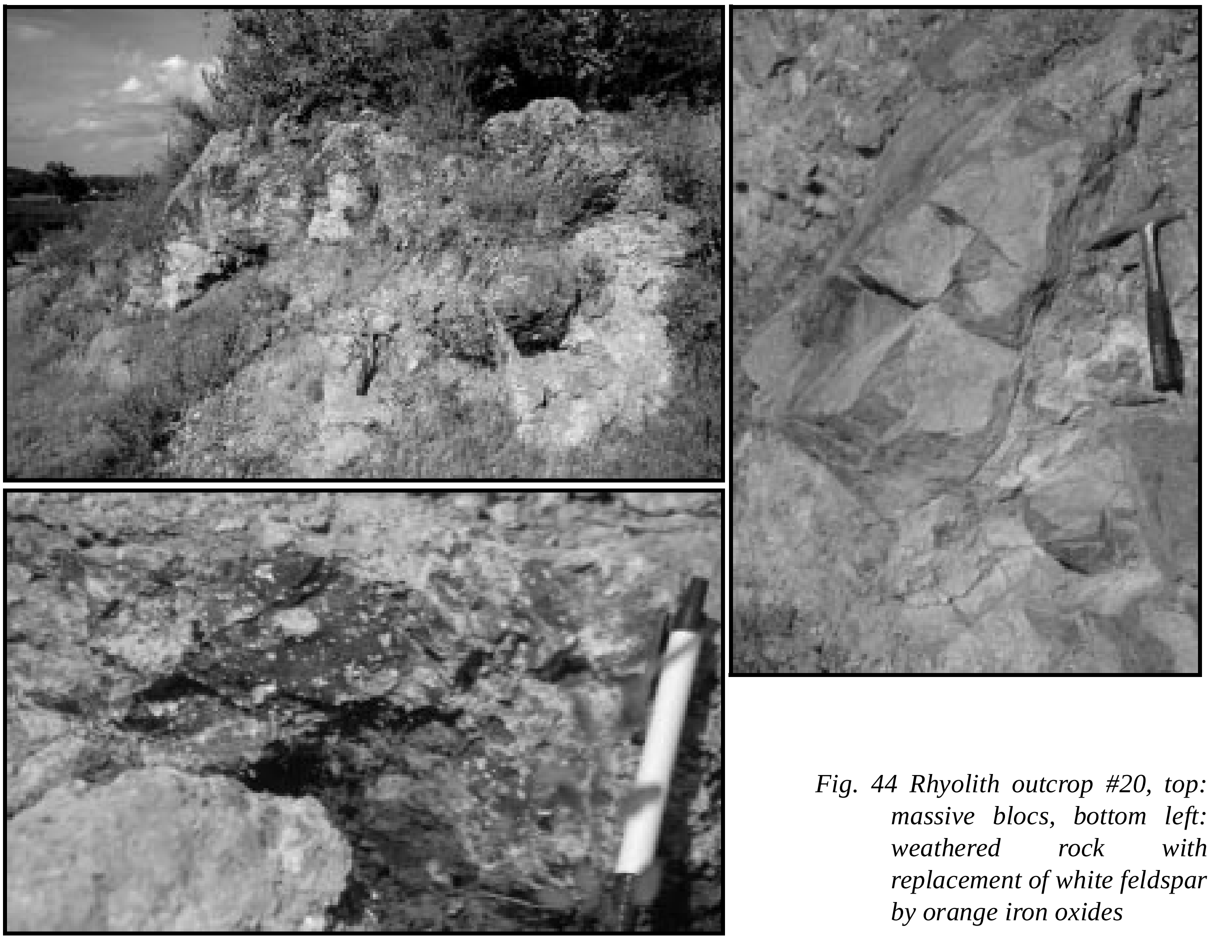


Fig. 44 Rhyolith outcrop #20, top: massive blocs, bottom left: weathered rock with replacement of white feldspar by orange iron oxides

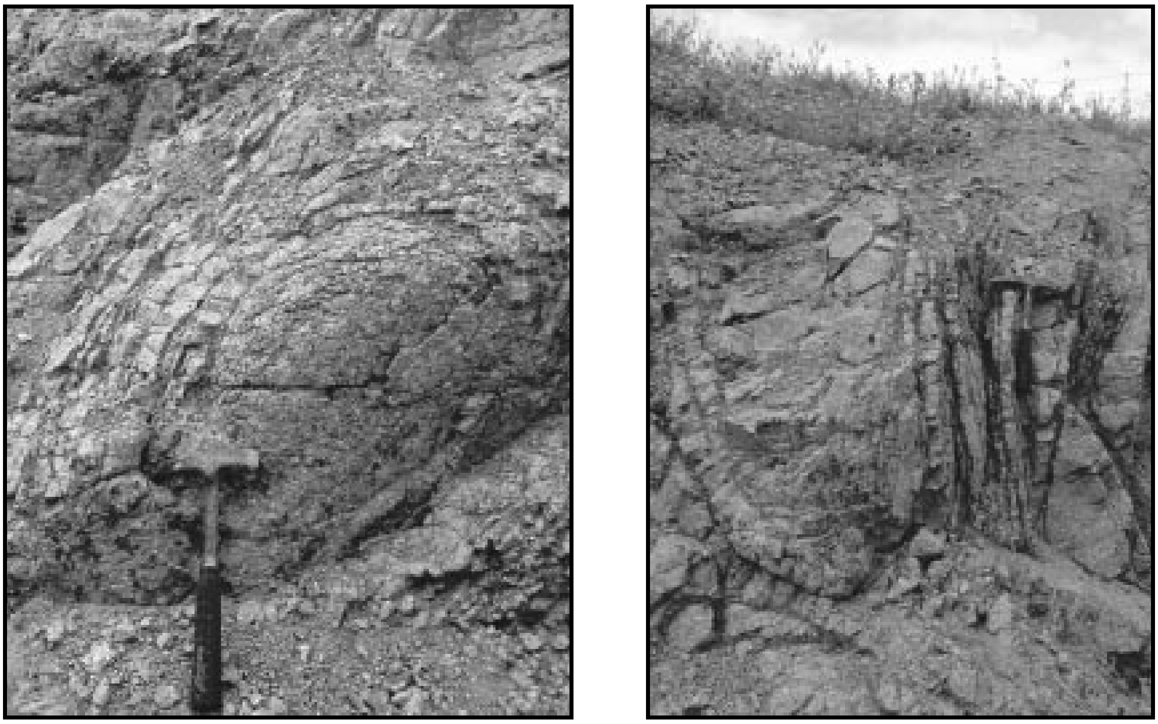


Fig. 45 Bended, fractured and spherically splitting rhyolith in outcrop #17

The rhyolith in the outcrops # 15 and #17 shows a strange shape: It is tectonically severly stressed, fractured in bancs of up to 5 cm, bended and spherical splitting (Fig.45). The whole rock is bleached, mafic minerals are replaced by iron oxides.

The contact of an intruded rhyolith and alterated El Doctor limestones is well documented at outcrop #24, an old quarry south of La Reforma (Fig.47). HOFMANN (1994) already described and examined a similar smaller outcrop west of La Reforma with alteration products in contact to unalterated El Doctor limestone. The x-ray diffractometry done in the this study showed the mineral composition with characteristical hydrothermal minerals (chapter 2.2.2.3.1).

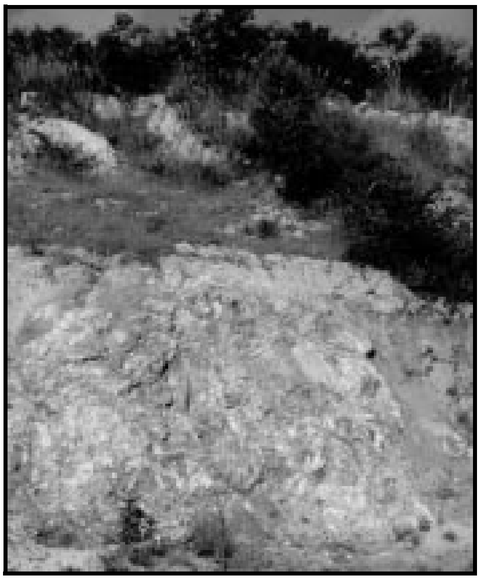


Fig. 46 View from the southeast through the quarry outcrop #24 (top), hydrothermal alteration zones (right)

Fig. 47 Outcrop #24: contact zone of an intruded rhyolith (bottom red) with Cretaceous El Doctor limestone (alterated orange)

Fig.47 shows the contact of the red rhyolith to the alterated ochre El Doctor limestone. The rhyolith contains several almost vertical calcite veins that probably filled fractures after the intrusion and alteration.

Only one location (outcrop #25) was found where volcanic rocks outcrop that were described as "glass tuffs" by de la PENA (1994) (chapter 2.2.2.3.1). The whole rock is layered with an interbedding of 1 mm to 3 cm thick red layers of iron rich feldspar and weathered white layers. On fresh cuts the white layers appear dark brown to black with a greasy shining and concoidal surfaces. Minerals show a flattening parallel to the layers and a preferential alineation (Fig.48).

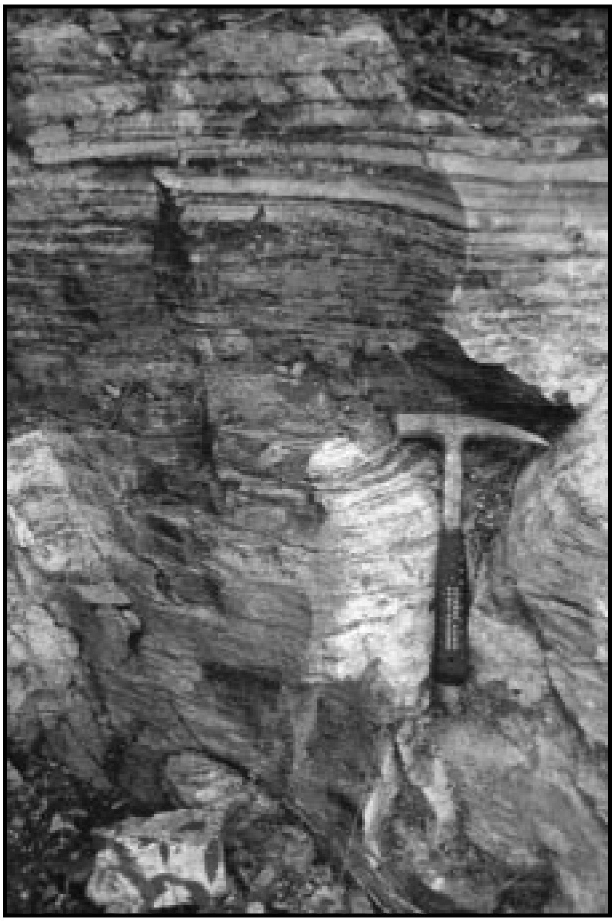


Fig. 48 Rhyolith with layered texture (outcrop #25)

4.1.2.2. Sediments

The existence of Tertiary sediments is suspected since the basin´s subsidence with consequent sedimentation already began in Tertiary (LABARTHE 1989), however no sediments in the whole study area were identified as certainly belonging to this age. The "Tertiary conglomerates" mapped in the official geological map 1:250,000 and 1:50,000 (CETENAL 1983 and 1976, chapter 2.2.1) were checked in several outcrops but couldn´t be confirmed. Mostly the supposed conglomerates turned out to be Quarternary chalky limestone outcrops. In case of outcrop #46 the "conglomerate" turned out to be a Quarternary tuff cone (reported as conglomerate in CETENAL 1976, as basalt in CETENAL 1983) and in outcrop #17 a Tertiary rhyolith. The only conglomerate that was confirmed is the calcareous conglomerate with El Doctor respectively rhyolith components from outcrop #7 (Tab.8). Maybe the coarser conglomerate is older (Tertiary / Quarternary), but at least the finer one seems to be younger. Since there was no age dating done and the examined outcrop density is quite low, the existence of these reported Tertiary conglomerates can´t be totally excluded but at least it is to question.

Tab. 9 Examined Tertiary outcrops

#	name	latitude, longitude	description
15	Roadside outcrop east of El Huizachal along an irrigation channel	a N 21°49.527´, W 099°54.106´ b N 21°49.546´, W 099°54.191´	10m W-E, 4-6m high, rhyolithes weathered in shells like in outcrop 17, but not weathered strong, shells are thikker and as well unweathered rocks
16	Rocks on hill El Capulin	N 21°49.815´, W 100°01.939´	some rhyolith blocs, poor outcrops, densely populated
17	Small quarry in Paso Real	N 21°50.625´, W 099°52.033´	50x30m, 4m high, totally weathered rhyolith, red feldspar (alcaline feldspar) bleached to light purple-pink, mafic minerals replaced by iron, only some quartz left unalterated, weathered in shells up to 5cm thick, [CETENAL (1976 and 1983): Tertiary conglomerate]
18	Hill north of Lago Tlacotes, outcrop in private estate	N 21°51.407´, W 100°02.155´	rhyolith blocs
19	Hill west of El Jabali	N 21°53.068´, W 100°03.371´	rhyolithes, in a roadside outcrop totally weathered to redish-yellowish-white-brown sand with single redish rhyolith blocs (-5cm max., mostly <1cm), fresh cut on rocks: red meat color, longly-rectangular, white feldspars (plagioclase) -1cm, less quartz, weathered darkgray with green clay minerals (serpentinite, chlorite) replacing the red feldspar from inside, mafic minerals replaced by redish-brown iron minerals
20	Hill E of San Diego dam	N 21°54.578´, W 100°05.932´	50m N-S, 2-4m high, rhyolithes partly totally weathered to yellowish soil, in less affected rocks white feldspar grains with yellowish contact zones, matrix dark red-brown
21	Rocks south of Milpa Larga	N 21°55.064´, W 100°07.325´	rhyolithes, extremely rich in Quartz, crystalls up to 5mm, very few hornblende and biotite, mostly severly weathered and bleached
22	Roadside outcrop west of Milpa Larga	N 21°55.415´, W 100°07.464´	15m N-S, about 2m high, rhyolithes
23	Rock face west of Milpa Larga	N 21°55.446´, W 100°07.629´	20mW-E, 6-8m high, rhyolithes
24	Quarry south of Ojo de Agua de Solana	N 21°58.222´, W 100°05.414´	hydrothermal alterated El Doctor limestones on the hill foot, on top of the hill unalterated El Doctor
25	Roadside outcrop south of the road El Jabali-Aguacate	N 21°52.847´, W 100°03.573´	20x10m, 6m high, layered red-white strata of 1mm-3cm thickness, white layers only weathered white, on fresh cut dark brown-black, concoidal fractured, greasy shining, quartz rich layers, quartz is flattened and elongated in preferntial direction, red layers iron rich feldspar

4.1.3. Quarternary

4.1.3.1. Lacustrine sediments

Quarternary lacustrine sediments cover the major part of the basin´s interior. They are widespread in the northern and eastern part but could be found also south of the fluvial sediments (chapter 4.1.3.2) in the southwestern part of the basin (outcrop #28). The sediments are mostly very fine grained to silty chalky limestones of a cremeous white to yellowish color sometimes with a black weathering cover.

Fig. 49 Typcial small-scale mining on chalk in the area between Rioverde and Pastora (outcrop #35a)

Outcrops are numerous due to the intensive karstification leaving open solution structures. Additionally north of Rioverde in the area of Pastora this chalky limestone is mined in small outcrops with a maximum size of 200 x 60 m and a depth of 4-8 m for building houses (Fig.49) and in 1999 also in larger outcrops as road building material for the new highway Rioverde-San Luis Potosi.

These calky limestones mentioned above are the first sediments to precipitate in the evaporation-precipitation-cycle of an aride lacustrine environment like in the Rioverde basin. The outcrops #33, #34, #35a and #35b, #36 show that in the Rioverde basin with continuing evaporation also gypsum was precipitated forming many small gypsum plates all over the rock (outcrop #33-#35) (Fig.50) or whole gypsum layers of 2-5 cm (outcrop #36, Fig.51).

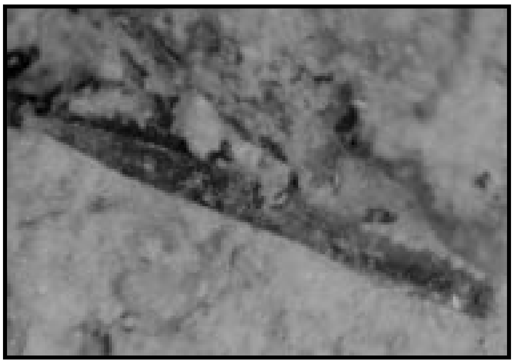


Fig. 50 Gyspum crystall in the microscope (length approximately 1.5 cm)

Fine sand layers interbedded in the calcareous material of the section in outcrop #36 reveal that there has still been some terrestric influence in the lacustrine environment. Hints for the precipitation of NaCl or KCl couldn´t be found, the general undersaturation of the sampled wells with regard to NaCl (App.No.32) seem to confirm that no significant amounts of this mineral were deposited in the study area.

Two lacustrine sediment samples were taken from outcrop #39 (chalk) and #35a (gypsum rich chalk) for an extraction with deionized water and further analysation with IC (ion chromatography) (App.No.18). The existence of gypsum in the sample from outcrop #35a was clearly proved with Ca concentrations of 630 mg/L and SO_4 concentrations of 1530 mg/L. Chlorine and Sodium were also slighlty increased compared to the chalk sample.

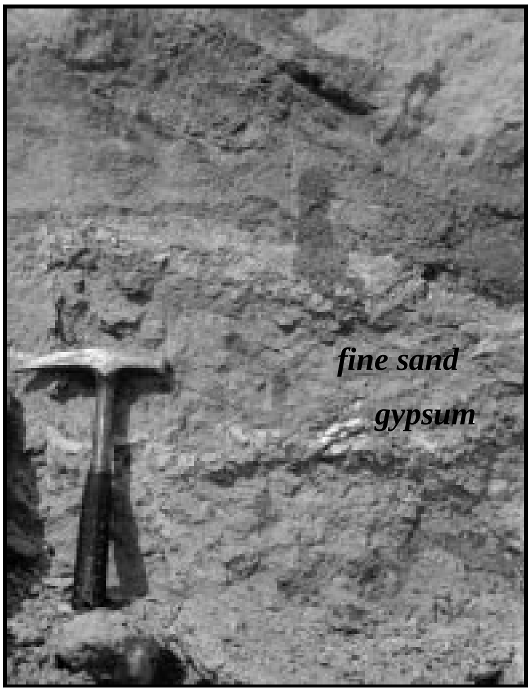


Fig. 51 Outcrop #36, interbedding of yellow fine sand layers and white layers with gypsum plates

Tab. 10 Examined Quarternary lacustrine outcrops

#	name	latitude, longitude	description
26	Outcrop north of Santa Isabel	N 21°50.193´, W 099°52.472´	open karst structure of chalky limestone
27	Roadside outcrop Paso Real	N 21°50.724´, W 099°51.815´	chalky limestones almost totally weathered to porous calcareous soil
28	Roadside outcrop south of the road El Jabali-Aguacate	N 21°52.862´, W 100°03.672´	white, chalky limestone
29	Hill west of Miguel Hidalgo	N 21°53.295´, W 099°54.692´	weathered light gray on fresh cuts yellow-white, chalky-calcareous, a little bit coarser than the other outcrops, besides red rocks up to 5cm non calcareous
30	Area between highway Rioverde-Ciudad Valles and Miguel Hidalgo	a N 21°54.338´, W 099°54.663´, b N 21°54.240´, W 099°54.393´ c N 21°53.930´, W 099°54.186´	several open karst structures, 100x50m max.size, often smaller, 1-2m deep
31	Hill on the road Rioverde-Ciudad Valles, west of Redencion Nacional	N 21°54.525´, W 099°55.215´	outcrops not very good, but roadside outcrop about 1m thick chalky limestone
32	Quarry Las Aguilas	N 21°54.750´, W 099°55.977´	50m diameter, mining of chalky limestone
33	Outcrops east of Rioverde	N 21°56.567´, W 099°57.834´	white to yellowish chalky limestone, gypsum plates
34	Outcrop northeast of Rioverde	N 21°58.386´, W 099°59.587´	white to yellowish chalky limestone, gypsum plates
35	Outcrops on the road Rioverde-Pastora	a N 22°00.682´, W 100°01.485´ b N 22°00.968´, W 100°01.369´, c N 22°02.783´, W 100°01.642´, d N 22°03.642´, W 100°02.199´, e N 22°08.478´, W 100°03.387´,	100x40m, 0.5-1m deep, 200x50m, 1m deep, 40x20m, 0.5m deep, 30x40m, 4m deep, 200x60m, 4-8m deep, many open karst structures of white to yellowish chalky limestone, stone is used for house building, in a and b visisble gypsum plates, sample for IC determination

# name	latitude, longitude	description
36 Quarry south of El Socorro (Otomite)	N 22°03.376´, W 100°03.430´	N-S 500m, W-E 70m, up to 6m high, next to the new highway, white-yellowish chalky limestone, very fine material, mined as road material, section with fine sand calcareous layers and whole layers of gypsum plates 2-5cm thick, also layers of orange-brown non calcareous sandy layers weathered with purple-black cover
37 Quarry east of El Socorro (Otom.)	N 22°04.560´, W 100°04.075´	big blocs of chalky limestone
38 Quarry east of El Socorro (Otom.)	N 22°04.858´, W 100°04.057´	big blocs of chalky limestone, mined for road material
39 Hill east of Diego Ruiz	N 22°06.687´, W 100°08.038´	weathered light gray on fresh cut yellow-white, calcareous-chalky, a little bit coarser than in the other outcrops, sample for IC determination

4.1.3.2. Fluvial sediments

Fluvial Quarternary sediments can be found only in outcrops in the southwest with the exception of a single outcrop (outcrop #43, Fig.54) in the northwestern part of the study area. The parent rocks of the gravel and sand pebbles are mainly rhyolithes, to a minor degree also Cretaceous limestones and in the northwest additionally basalt fragments. The components are well to perfectly rounded indicating a transportation of more than 1-5 km for the limestone blocs and more than 10-20 km for granites or rhyolithes (ZEIL 1990) from the mountaineous area to the west.

Fig. 52 Hill near San Diego, next to Morales river, build from Quarternary sand and gravel (outcrop #40)

Additionally the outcrops #41 and #42 show some clay share (Fig.53) like the drilling Sainacio (Fig.71). From the latter a sample was taken for the simulated silicate weathering (ICP-MS) (chapter 3.1.1.1). Ba, Pb, Nd, Pr, Ce, La, Y, Th and As were significantly, Zn, Sr and Mn slightly increased in the determined solution.

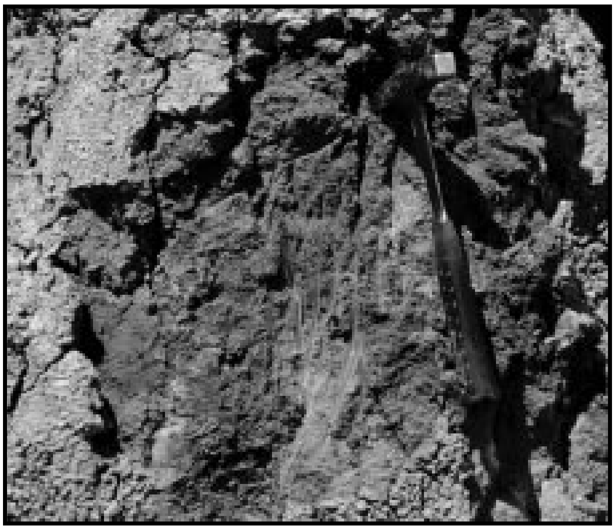


Fig. 53 Fine sand and gravel but also clay present the Quarternary geology of the basin´s southwestern part (outcrop #41)

Fig. 54 One single "cliff" of fluvial Quarternary in the northwestern part of the basin (outcrop #43) and a close-up on weathered rhyolith pebbles (outcrop #42)

Tab. 11 Examined Quarternary fluvial outcrops

#	name	latitude, longitude	description
40	Hill east of San Martin, northern riverside of river Morales (opposite a waste disposal)	N 21°55.303´, W 100°05.886´	500m W-E, about 16m high, river sediments, sand and gravel with components from several cm up to 1m, mainly severly weathered rhyolithes well to perfectly rounded, some limestone components angular to rounded, in the eastern part of the outcrop no layering visible, in the western part layering of fine sand with gravel strata of about 1-2m thickness at the bottom, coarsing upward cycle
41	Hill in San Martin	N 21°55.489´, W 100°06.146´	5m W-E, about 6-8m high, river sediments, mostly sand, some clay share, some rhyolith gravel, average size 10cm diameter, max.50cm
42	Roadside outcrop north of San Martin	N 21°55.921´, W 100°06.164´	10m W-E, 2-4m high, gravel with sandy-clayey uncemented material, rhyolith components max.50cm, whole gravels replaced by clay
43	Small quarry near La Penita	N 22°01.248´, W 100°02.557´	10x20m, 6m high, gravel and sand, components well rounded, mostly rhyolithes, plus basalts, up to 15cm diameter, some parts cemented with white calcareous material (aggregates up to 50cm diameter)

4.1.3.3. Volcanic rocks

Quarternary volcanics cover basalts, tuff and scoria and are found only in the northwestern part of the basin. The black basalts have a porfiric texture and contain some olivines and granates. West of Las Cucharas the basaltic columns form two small hills (outcrop #44). The larger basaltic area north and west of La Penita also mapped in the official geological map (CETENAL 1976) could be proved only by some rocks (outcrop #45), the one west of Pastora wasn´t found at all, but the area was quite inaccessible.

A small hill southwest of Pastora mapped as "conglomerate" in the map 1:50,000 (CETENAL 1976) and as "basalt" in the map 1:250,000 (CETENAL 1983) turned out to be a tuff cone. The outcrop conditions were excellent since the whole hill is mined for these tuffs (Fig.55, Fig.56).

The most significant characteristic in the outcrop of black porous tuffs is an almost vertical, white basalt dyke striking NE-SW. In the northeastern part of the quarry the extension of the basalt dyke is not outcropped but there is an area of intensive alterated redish-white tuffs (Fig.57 bottom right). On the other side (NW) the tuff is totally alterated and weathered to yellowish tuff soil. In the southwestern part of the quarry some scorias were found (Fig.57 left) and very rarely bombs (Fig.57 top right).

Samples were taken from the redish-white tuff rock and the alterated tuff soil for simulated silicate-weathering (ICP-MS) (chapter 3.1.1.1). The yellow extraction solutions had a light, in case of the tuff soil an intensive smell of H_2S. Significantly increased trace and minor elements are Ni, Cr, Cu, Mo, Sr, Al, Fe, Mn, Zn and Ba. Arsenic and uranium concentrations are remarkably low (App.No.17).

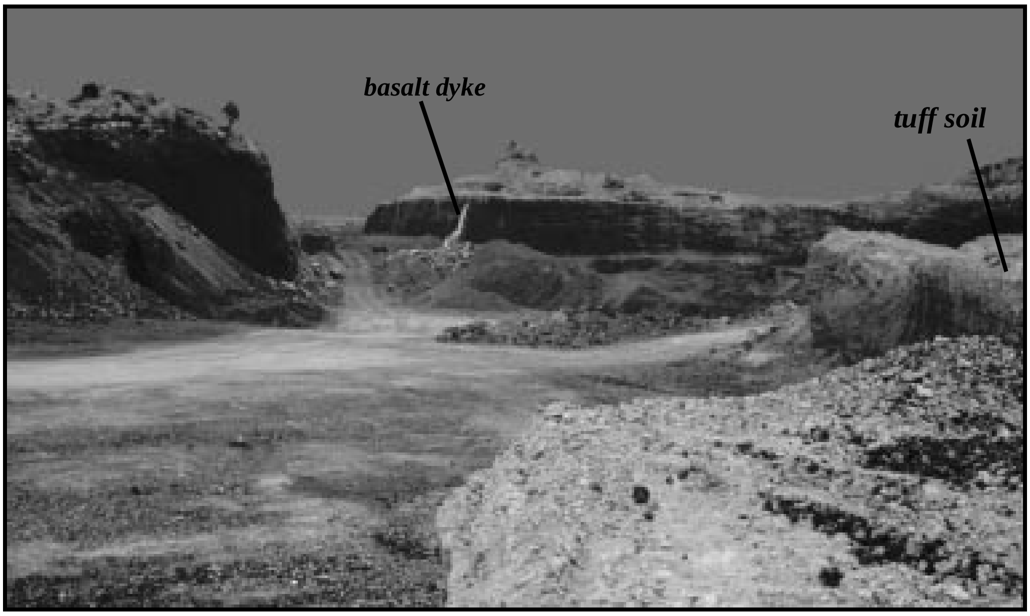


Fig. 55 Quarry tuff cone Vergel - view from the north to the south

Fig. 56 Quarry tuff cone Vergel - view from the south to the north

The age determination of the tuff and the basalt is difficult since no dating exists so far. In the official geological map (CETENAL 1976 and 1983) they are outlined as Quarternary basalts, but de la PENA (1994) and LABARTHE (1989) report them to belong to the Miocene-Pliocene respectively Oligocene-Pliocene age (chapter 2.2.2.3.1). In contrast to this the basin´s development indicates that probably the basalts and tuffs intruded *after* the lacustrine sediments were deposited in the Quarternary. Chalky limestones with tuff fragments inside found in the vicinity of the tuff cone prove that at least the intrusion of the tuff took place after the evaporites´ sedimentation.

To ensure this a rock sample was taken from the tuff cone for thermoluminiscence dating, but as it was already mentioned in chapter 3.1.1.2 the age determination was not completed in time for this report.

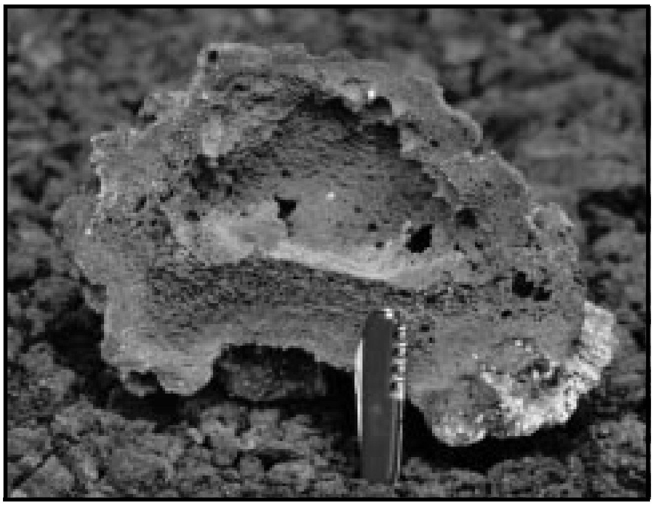
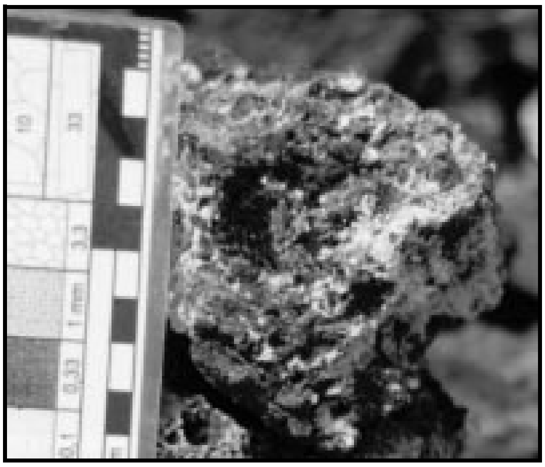




Fig. 57 Quarry tuff cone Vergel - scorias (above), a volcanic bomb (top right), and alterated tuff rock (bottom right)

Tab. 12 Examined Quarternary volcanic outcrops

# name	latitude, longitude	description
44 Hills west of Las Cucharas	a N 22°01.234´, W 100°04.952´, b N 22°01.283´, W 100°05.034´	darkgray basaltic columns building the hill, black, porfiric basalt contains some olivine and red granates
45 Rocks north of Loma Las Auras	N 22°02.201´, W 100°03.331´	darkgray-black basalt with some weathered granate minerals
46 Quarry tuff cone Vergel	N 22°07.243´, W 100°04.486´	morphologically characteristic tuff cone with mainly black porous tuffs, in parts purple-red-brown scoria and a white basalt dike; alterated parts in the northeast of the quarry; distributi-on area: Rocks (tuff and white chalky limestones with black tuff pieces included) along the road Pastora - Chamizal and Vergel and to the west up to N 22°06.717´, W 100°07.569´ Rock samples: 1 for dating with ther-moluminiscence and 2 for simulated silicate-weathering extraction [CETENAL (1976): Tertiary conglo-merate; CETENAL (1982): basalt]

4.1.3.4. Caliche and Travertine

Travertine covers large areas between the karst springs Media Luna and Anteojitos as well as areas in the southeastern part of the basin where there are several smaller karst springs (Palmas Largas, Charco Azul, Sonora, etc.). Two different types of travertine were found, a more widespread massive, white travertine and a yellowish travertin building thin calcareous layers (outcrop #52).

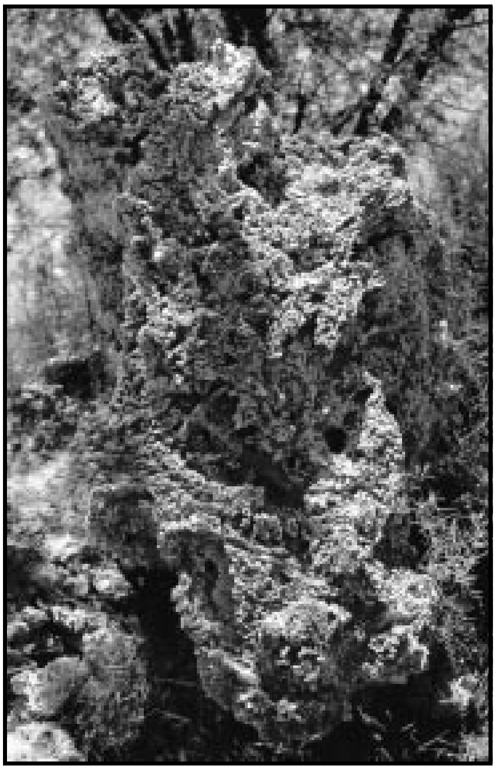


Fig. 58 Large flat areas formed by travertine (outcrop #48e, above) and close-up of a travertine bloc (outcrop #48d, right)

The white travertine with a darkgray weathered surface forms large flat areas with spare vegetation in the southwestern part due to the Ca-rich water from the big springs Media Luna and Anteojitos (Fig.58).

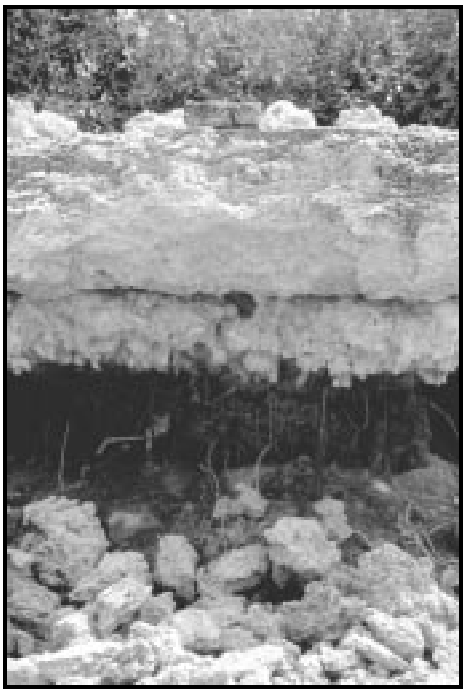


Fig.59 demonstrates clearly how recent the travertine formation is covering Holocene soil. Besides these relatively thin travertine layers there are as well large blocs of several meters (10-15m) building the rio verde riversides near Puente Barestegui (outcrop #53, Fig.60 right). The origin of this travertine is probably owed to an additional groundwater outlet at the western side of the river, near Rioverde´s waste water discharge. Especially these travertine blocs are extremely rich in fossils (Fig.60 left).

Fig. 59 Travertine covering soil (outcrop #47)

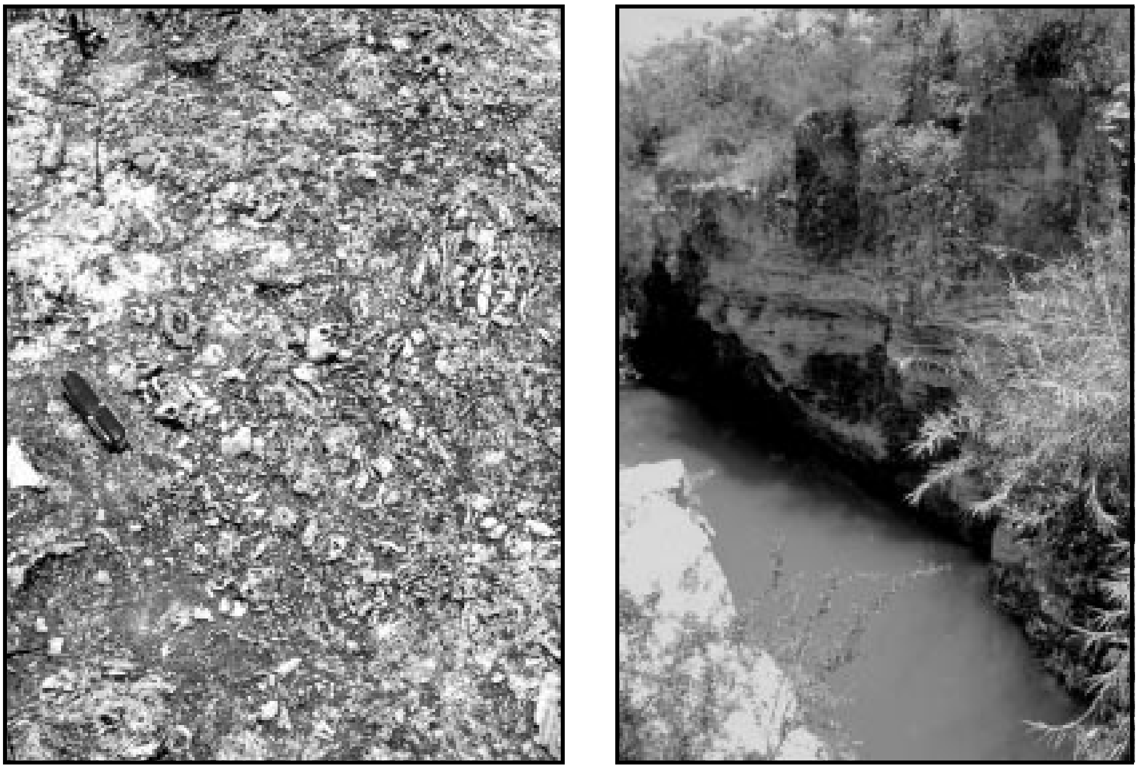


Fig. 60 Travertine forming massive blocs rich in fossils and calcificated plants on the riversides of the rio verde (outcrop #53a)

The second type of travertine contains less fossils, has a yellowish color and forms up to 5 cm thick calcareous layers (outcrop #52, Fig.61).

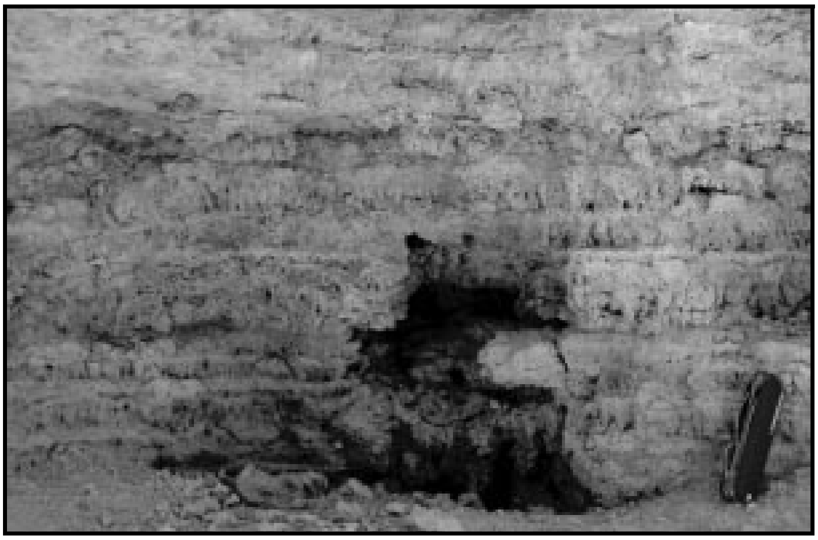


Fig. 61 Travertine in thin bancs (outcrop #52)

In previous projects the distinction between caliche, as carbonatic concretions in soils precipitated either from infiltrated rain water or groundwater flow orientated upwards, and travertine, as a carbonatatic precipitation in the vicinity of springs due to the degassing of CO_2, was not done. Thus large areas were described to be covered with "caliche and travertine" (de la PENA 1994, HOFMANN 1994). Basicly during this field work only 3 sites were found to be provable caliche.

Outcrop #49 (Fig.62) shows the oldest caliche, about 4-6 m thick, including a 50 cm thick soil layer with preserved roots. Probably it precipitated from groundwater of the El Doctor limestones.

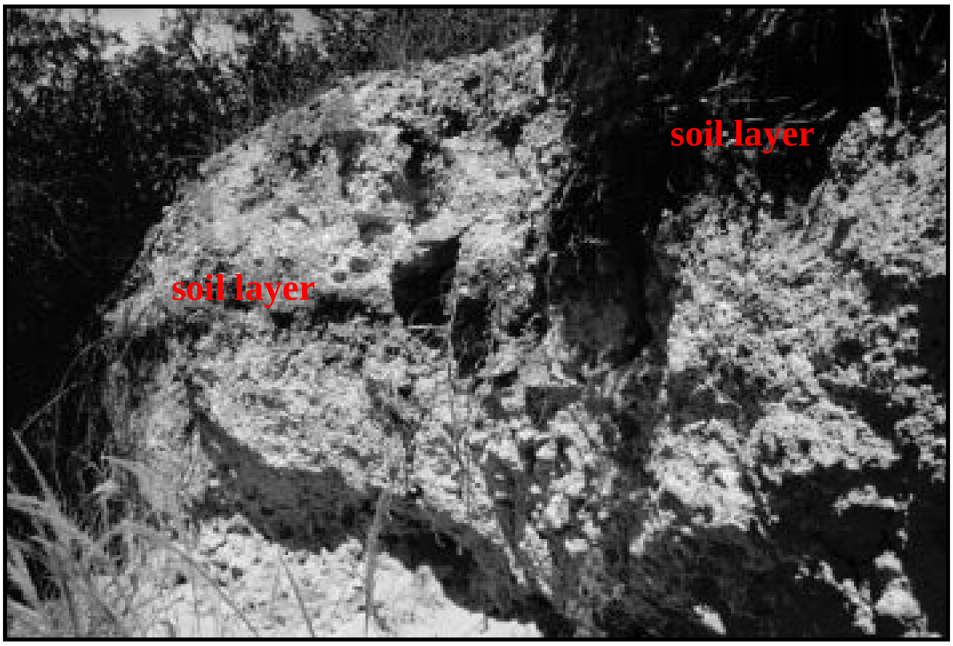


Fig. 62 Caliche with a 50cm thick soil layer included (outcrop #49)

Close to the river at outcrop #53a there is a sharp contact between the fossil rich travertine and an extremely white limestone, without fossils, weathered with a smooth surface that often contains soil residues inside (Fig.63), which is also supposed to be caliche.

Fig. 63 Sharp contact between white massive caliche on the bottom and gray travertine above (outcrop #53a)

The most recent caliche is found in outcrop #53c with very tiny (max. 1 cm in diameter) calcareous concretions in a brown fine sandy soil over travertine (Fig.64).

From outcrop #53a one sample was taken from the caliche and one from the travertine for the simulated silicate-weathering extraction (ICP-MS) (chapter 3.1.1.1). In the travertine sample especially Ni, Zn, U and Ba were increased while in the caliche sample uranium concentrations were not detected at all, Zn, and Ba were considerably lower. Arsenic concentrations however were determined to be about twice as high as in the travertine (App.No.17).

Fig. 64 Soil section over travertine (left) and close-up of the tiny calcareous concentretions it containes(above)

Tab. 13 Examined Caliche and Travertine outcrops

#	name	latitude, longitude	description
47	Outcrop La Borcilla	N 21°51.363´, W 099°53.893´	50cm yellow travertine over soil layer
48	Area between Media Luna and Anteojitos, north of the eastern Media Luna irrigation channel	a N 21°51.238´, W 099°59.628´, b N 21°51.264´, W 099°59.649´, c N 21°51.479´, W 099°58.104´, d N 21°51.481´, W 100°00.322´, e N 21°51.504´, W 099°59.735´, f N 21°51.896´, W 099°59.828´, g N 21°52.235´, W 099°59.845´	white travertine from some cm up to 3m thick, outcrops are solution structures, whole area is flat with a bare darkgray weathered cover, travertine as well on both sides of the road from Palomas - Bordo Blanco - El Carmen
49	Outcrop west of the road highway SLP-RV to Media Luna (waste disposal)	N 21°52.449´, W 100°02.359´	N-S 300m, W-E 70m, 2-8m high, on the southern side: white porous calcareous material interbedded with 50cm thick soil layers with preserved roots, probably caliche
50	South of Acequia Salada	a N 21°52.088´, W 099°54.960´, b N 21°53.079´, W 099°55.066´	white travertine, also on both sides of the irrigation channel from Acequia Salada
51	Roadside outcrop Miguel Hidalgo	a N 21°53.201´, W 099°54.254´ b N 21°53.291´, W 099°54.327´	white travertine
52	Old quarry southeast of Puente el Carmen	N 21°54.008´, W 099°57.923´	yellow travertine in layers of up to 5cm thickness
53	Outcrop on the west riverside of the rio verde (Puente Berastegui)	a N 21°55.206, W 099°57.968´	from the river the lowest 2m extremely white limestone, weathered with a smooth surface, inside often soil residues, probably caliche; above these 2m travertine extremely rich in fossils, weathered gray-black, uneven surface, probably due to additional groundwater outlet (wet area of small springs near waste water pipe), sample for simulated silicate-weathering extraction from travertine and caliche
		b N 21°55.528´, W 099°57.893´	10-15m thick white travertine brown fine sandy soil with calcareous concretions (max.1cm in diameter),

#	name	latitude, longitude	description
53	Outcrop on the west riverside of the rio verde (Puente Berastegui)	c N 21°55.466´, W 099°57.905´	partly rebuilding root channels, over travertine, probably caliche
54	roadside outcrop on the northern riverside of the rio verde on the road to Pastora	N 21°57.189´, W 100°00.630´	yellowish-white travertine plant relicts up to 15cm

4.1.3.5. Soil

A strange feature found in the southwestern part were artifical soil outcrops. One area still in use and two old ones were found where soil is excavated about 2 m deep. The shape of the outcrops (Fig.65) and the red wooly gras covering the abandoned areas (Fig.66 top) remind of peat cutting, but even if the soil section shows a slight enrichment of humic matter (Fig.66 left), there was no real hint for peat ocurrence. The question what is "mined" here and for what it is used couldn´t be settled.

Fig. 65 Artificial outcrop reminding of peat cutting (outcrop #55)

Fig. 66 Humus rich soil section (left) and the red wooly gras covering the abandoned artificial outcrops (above) (outcrop #55)

Tab. 14 Examined Quarternary soil outcrop

#	name	latitude, longitude	description
55	Artificial outcrops east of road San Martin-highway SLP-RV	N 21°57.091´, W 100°05.700´, N 21°56.971´, W 100°05.555´, N 21°57.052´, W 100°05.845´	350x500m, about 2m deep; 100x15m, about 2m deep, old one; 100x40m, about 0.5m deep, old one; old outcrops covered by red gras

4.2. Drillings and geophysical sections

The location of the drilling sites and the geophysical cross-sections is indicated in the digital tntmips altas [file geology, drillings_data respectively geophysics_data]. The following description will present groups of geophysical cross-sections and drillings from the south to the north.

4.2.1. Southeast: Las Magdalenas - well No.141- El Huizachal

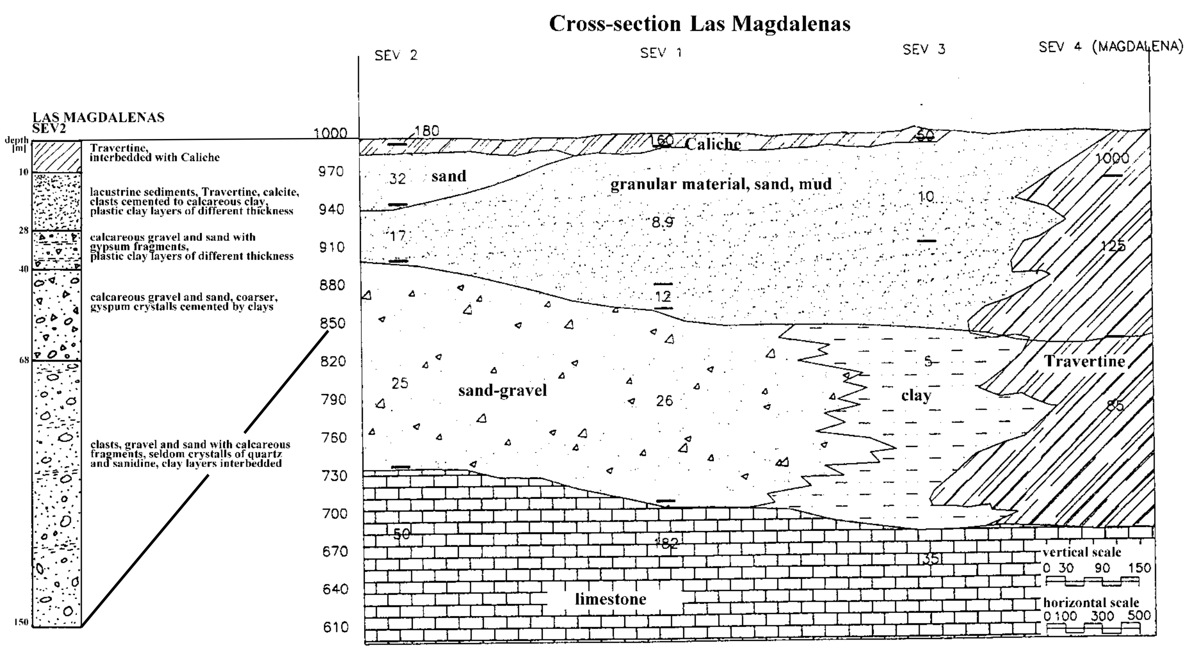


Fig. 67 Cross-section Las Magdalenas - Geophysics (modified from CHAM 1998) and drilling SEV 2 (1998)

The Pre-Quarternary geology of the southeastern part seems to be quite simple: Cretaceous limestones in the basin (Las Magdalenas) surrounded by rhyolithes on the southern border (El Huizachal). The depth of the basin floor was interpretated to be at 270-320 m in Las Magdalenas, confirmed by the 150 m deep drilling that didn´t hit the limestone, and about 300 m in El Huizachal, where the consequent drilling revealed that alterated rhyolith was already met at 22 m.

For Quarternary well No.141 and the profile Las Magdalenas both show interbedding of sand and gravel indicating a former riverbed, but in Las Magdalenas the 200 m river sediments are covered by 100 m fine sand and mud maybe showing a shift of the old riverbed towards the north followed by floodplain or lacustrine environment. The same low energetic sediments in El Huizachal are probably owed to it´s location near the Sierra outside the river sedimentation zone. The youngest rock formation, the chemical sedimentation of travertine, shows a maximum thickness of 300 m in SEV 4 Las Magdalenas.

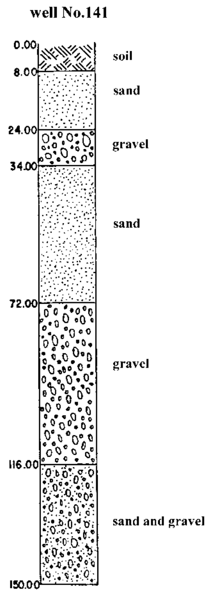


Fig. 68 Drilling well No.141 (modified from SECRETARIA DE AGRICULTURA 1984) (above)

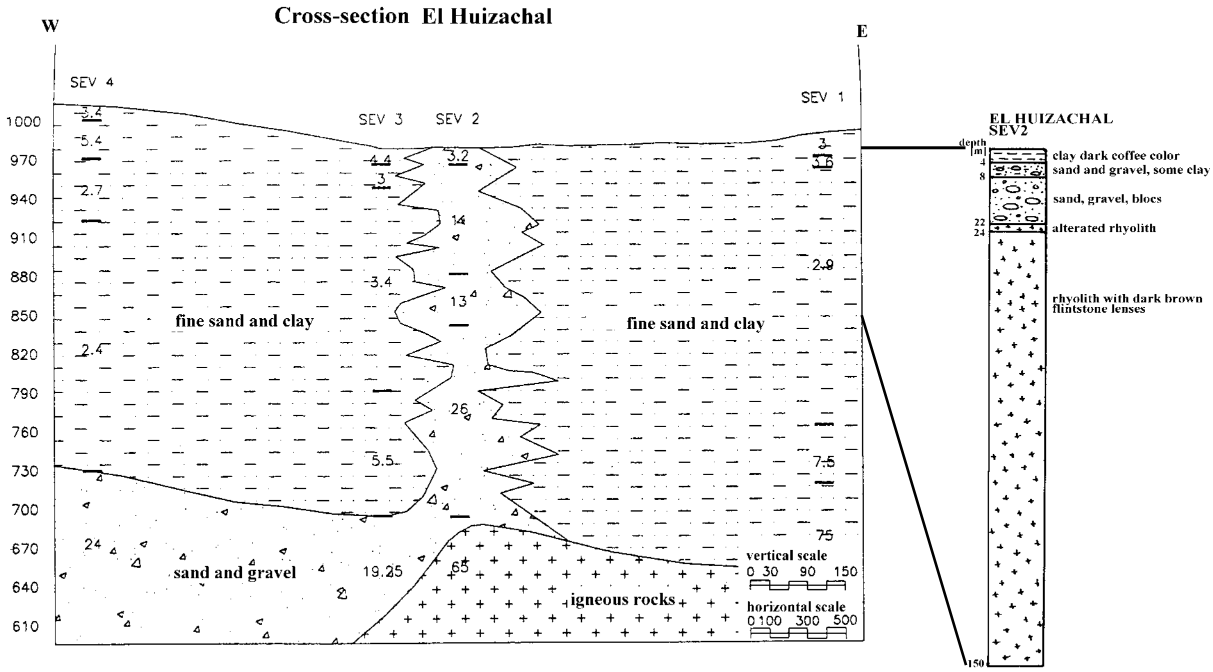


Fig. 69 Cross-section El Huizachal - Geophysics (modified from CHAM 1998) and drilling SEV2 (1998)

4.2.2. Southwest: La Loma - El Jabali

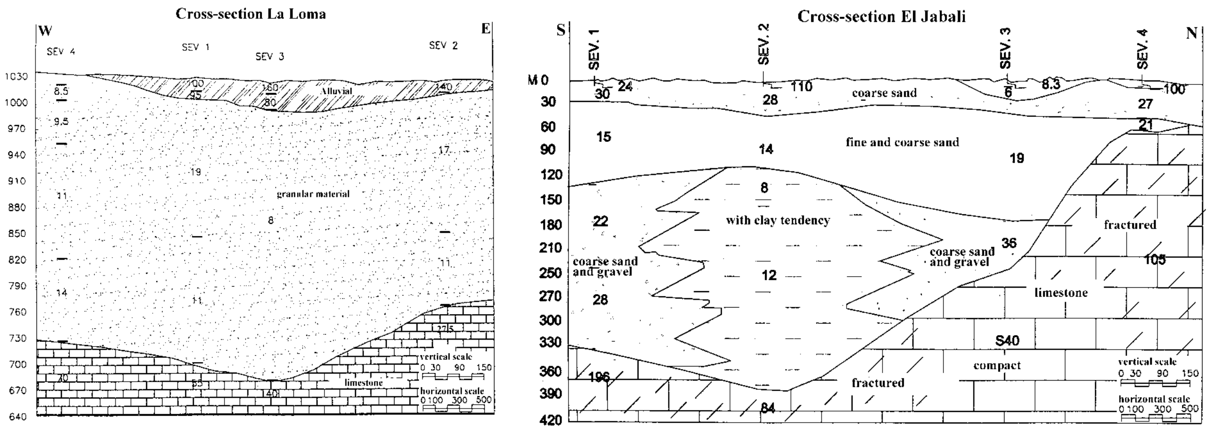


Fig. 70 Cross-sections La Loma (left) and El Jabali (right) (modified from CHAM 1998)

The basin floor in the southwestern part is like in the southeast build of Cretaceous limestone at depths of 300-320 m (La Loma) and 60-370 m (El Jabali). It seems strange that in SEV2 El Jabali located close to a Cretaceous outcrop limestone occurs at a depth of 370 m while in SEV 4 further north in the basin at 60m. If this is true it would indicate that the Cretaceous hill south of El Jabali is not just a morphological elevation but a tectonical scale bordered by faults explaining the sharp vertical contrast of more than 370 m in only a few hundred meters of horizontal distance.

Quarternary sediments contain coarse and fine sand and gravel typical for riverbeds, but the clay layers in drilling Sainacio and clay lenses in El Jabali also show confined areas of low energetic environment, maybe small puddles in a river delta system. The fine granular material in La Loma maybe interpretated only as debris from the nearby Sierra, not necessarily river sediments.

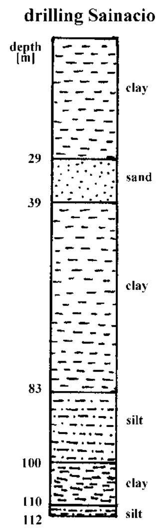


Fig. 71 Drilling Sainacio (1998) (above)

4.2.3. West: well No.13 - La Tapona - El Tecomate - Ojo de Agua de Solana

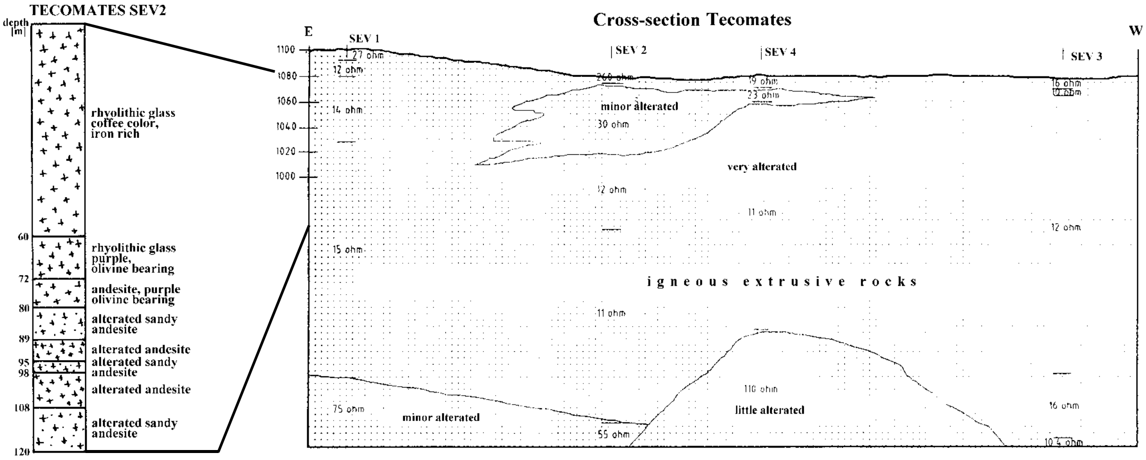


Fig. 72 Cross-section Tecomates -Geophysics (modified from CHAM 1998) and drilling SEV 2(1998)

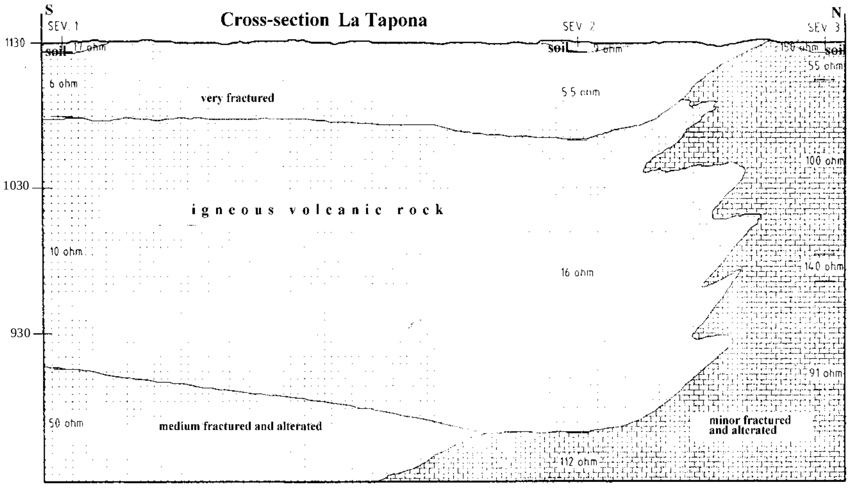


Fig. 73 Cross-section La Tapona (modified from CHAM 1998)

The geophysical sections of Tapona and Tecomates are already located in the western Sierra, the differences in geophysical resistances are interpretated as varying alterated and fractured rhyolithes, corresponding with the drilling report from Tecomates.

No. 13, the drilling that is located furthest to the west 3 km north of the rio verde shows 34 m fluvial gravel and sand overlying limestones, indicating the influence of an old riverbed close to the recent. This is also confirmed by the geophysical section Ojo de Agua de Solano close to the rio verde with max. 420 m sand and gravel. SEV 2 and SEV 1 the sites closest to today´s riverbed show the coarsest sediments, SEV 3 north of the rio verde shows characteristic fine sand and mud of the fluvial flooding plains. Maybe the riverbed shifted a little bit to the south in the past, since with depth the coarse sediment fraction increases in SEV 3 and the fine sand and mud fraction in SEV 1. According to the geophysical interpretation limestone was reached in about 330 m in SEV 3.

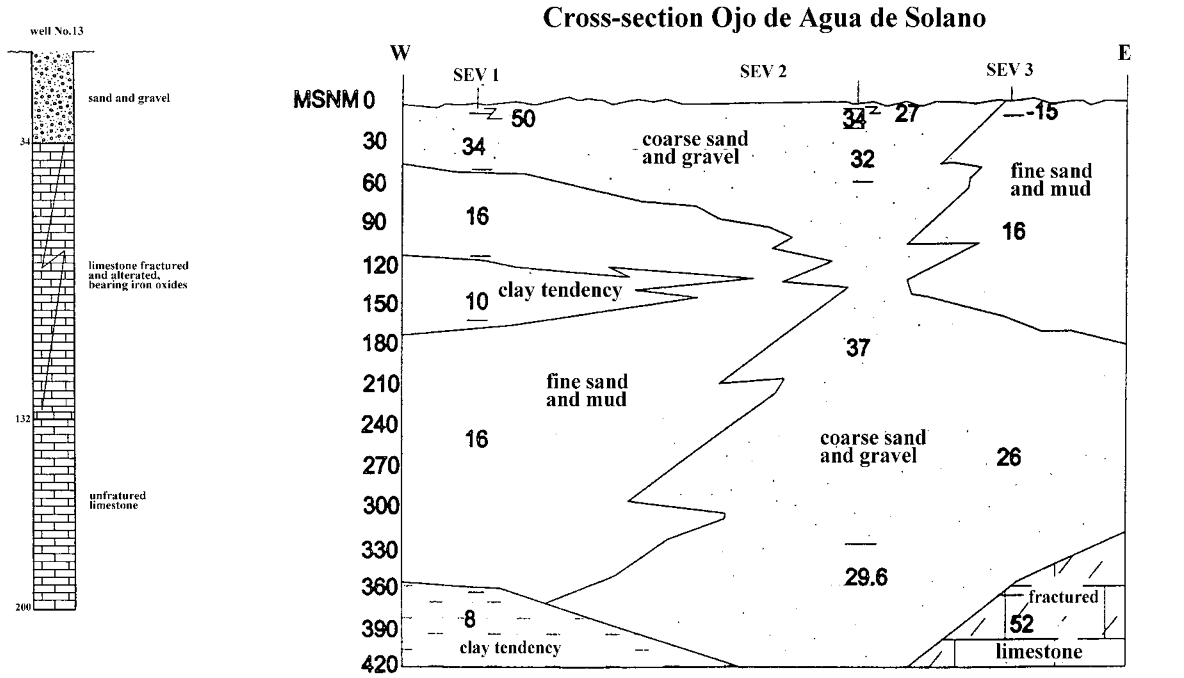


Fig. 74 Drilling well No.13 (modified from SECRETARIA DE AGRICULTURA 1984) (left) and cross-section Ojo de Agua de Solano (modified from CHAM 1998) (right)

4.2.4. Central: well No.20 - well No.142

While drilling No. 20 2 km north of the rio verde still shows 42 m just fluvial sand and gravel above limestone, in drilling 142 about 8 km north of the river 350 m of varying sediment were drilled. Gravel and sand are interbedded with 2-38 m thick "calcareous clay" (chalk) layers, indicating a border zone between fluvial and lacustrine environment.

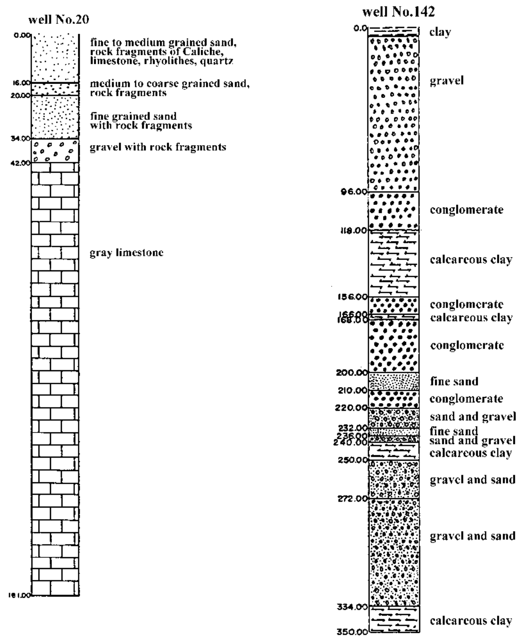
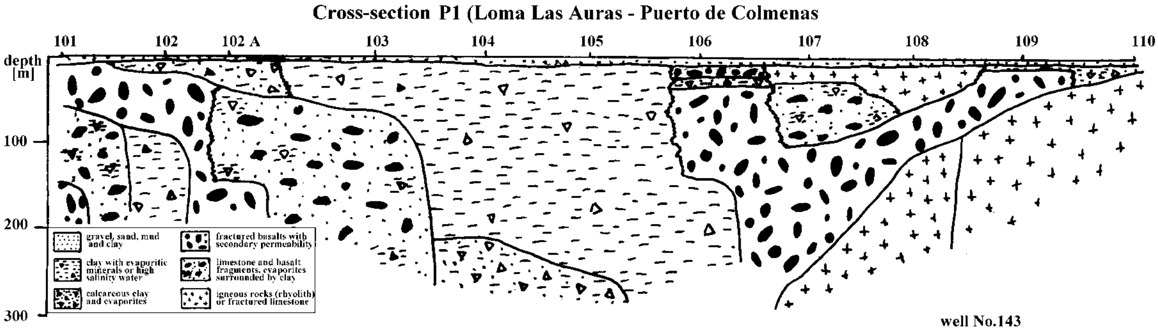


Fig. 75 Drilling well No. 20 and 142 (modified from SECRETARIA DE AGRICULTURA 1984)

4.2.5. Centralnorth: P 1 (Loma Las Auras - Puerto de Colmenas) - well No.143



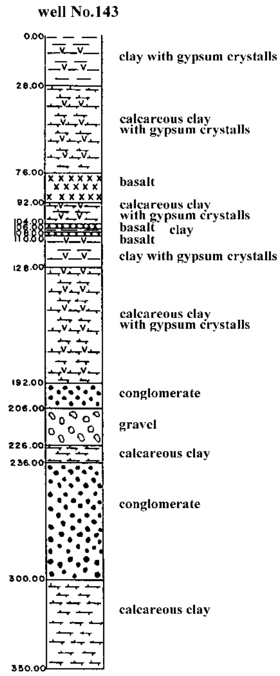


Fig. 76 Cross-section P1 (modified from SECRETARIA DE AGRICULTURA 1980) (above) and drilling well No.143 (modified from SECRETARIA DE AGRICULTURA 1984) (right)

Well No. 143 about 25 km north of well No. 142 shows no fluvial influence anymore, mainly chalk with some gypsum crystalls was deposited. Thin basalt layers interbedded indicate volcanic activity in the Quarternary. Profile P1 also shows large areas of Quarternary basalts, confirmed in the west by outcropping basalt hills (outcrop 44a and 44b), only suspected in the east since they are covered by younger sediments there. The underlying rock, probably limestone, was only hit in the eastern part (points 107 to 110), in the basin´s interior more than 300 m chalk with evaporites (gypsum) cover the basin´s floor. For the points 104 and 105 an increase in gypsum content is reported in more than 200 m depth.

4.2.6. North: P2 (Puerta del Rio - La Gavia) - P3 (Angostura - La Muralla) - La Muralla

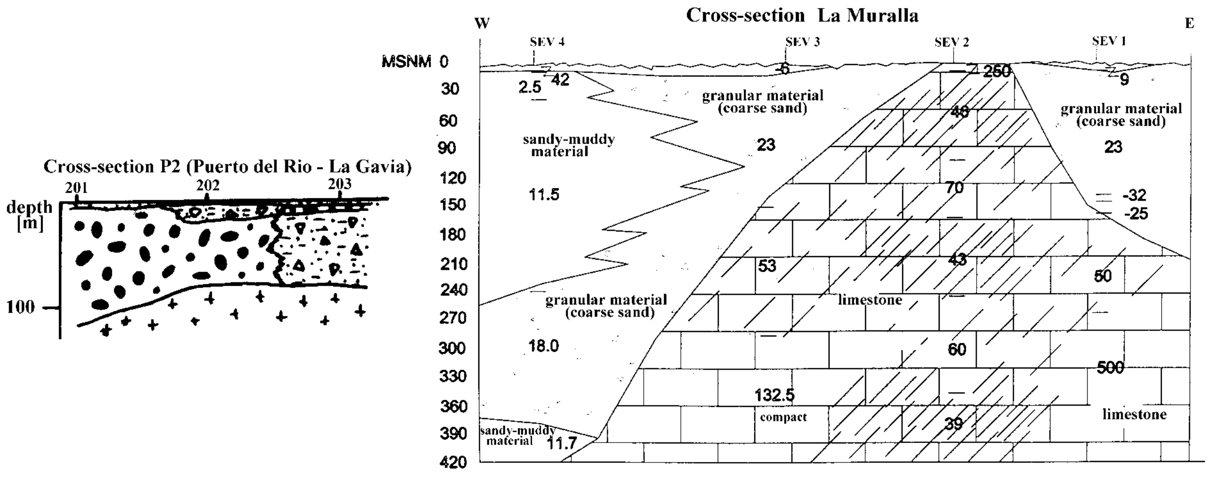


Fig. 77 Cross-sections P2 (left) (modified from SECRETARIA DE AGRICULTURA 1980) and La Muralla (right) (modified from CHAM 1998)

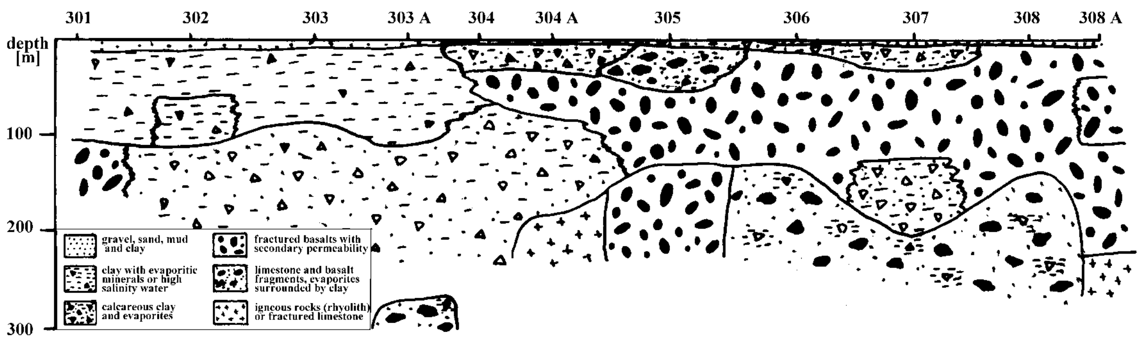


Fig. 78 Cross-section P3 (modified from SECRETARIA DE AGRICULTURA 1980)

In profile P2 located already outside the basin sensu stricto (northwestern elongation Villa Juarez-San Cirro) the underlying limestone was hit in only 100 m depth. Basalts cover it in the western part, chalk with gypsum in the eastern part. P3 continues with the chalk-gypsum sediments in it´s western part, showing an increase in gypsum content in more than 100 m like P1. In the eastern part large areas of basalt were found covered by a thin layer of chalk. Profile La Muralla located north of the western part of P3 shows limestone in more than 420 m depth (SEV4) and outcropping in SEV2. The granular material of coarse sand north and west of SEV2 are just debris from the limestone hill SEV2 dovetailing to the basin´s interior with the sandy-muddy chalk.

4.3. Tectonical structures

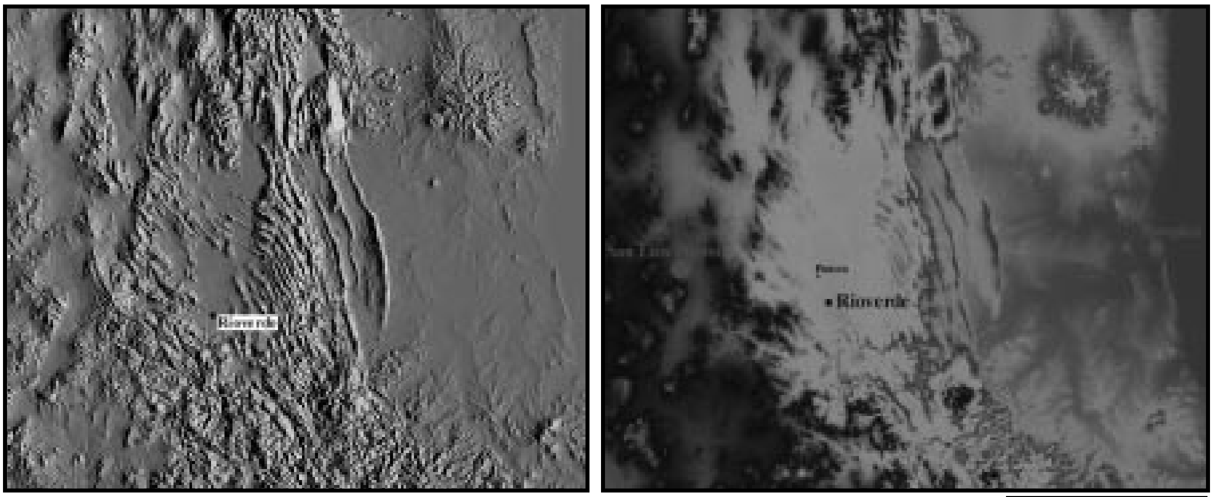


Fig. 79 Rioverde basin and surroundings - DEM black-white shaded relief (90°azimuth, 40° elevation, z=12) and false color (color palette: modified "rainforest") (program: tntmips, scale: approximately 350 km from the west (Sierra Madre Oriental) to the east (coast Golf of Mexico))

The two images (Fig.79) show the structural surrounding of the Rioverde basin (darkpink with the small San Cirro-Villa Juarez elongation to the NW lightpink). The alternating lightblue-pink, slightly bended structures in it´s northeastern part indicate valleys and ridges reminding of the Basin and Range Province in small scale. Anyway there is no strict border to the north, another Y-shaped depression extends further north until finally at the picture´s margin the mountains of the Sierra Atravesada (darkblue, brown) put a morphological easily recognizable limit. To the west the basin is clearly bordered by the Sierra (darkblue, brown), large faults redraw this border in the southwestern part of the basin continuing much further to the south (darkred). These faults coincide with the southern elongation of the former Cretaceous platform (Fig.10). To the east there is a significant morphological step east of Ciudad Valles (darkred line striking N-S all over the picture) presenting the eastern margin of the former Cretaceous platform. The green areas in the east show the coastal delta flooding plains with the rivers flowing to the Golf of Mexico (darkblue-purple).

For structural analysis a rose diagram with weighted sectors was calculated for the whole study area and for two selected areas, one in the northwest with mainly Cretaceous limestone, the other in the southwest with mainly Tertiary rhyolithes. Fig.80a shows that there are two main structural directions: NW-SE (70-140°) and NE-SW (50°, but also 10 and 20°). The NW-SE direction, that predominates in the Cretaceous limestones (Fig.80b) but also in the alignment of the basin and range province in the northeast, the big faults in the southwest or the general orientation of the basin, seems to be the older structure, active at least since Cretaceous. This direction is cut by the younger NE-SW orientated elements probably related to the extensive regime in Tertiary causing the extrusion of volcanic rocks (Fig.80c).

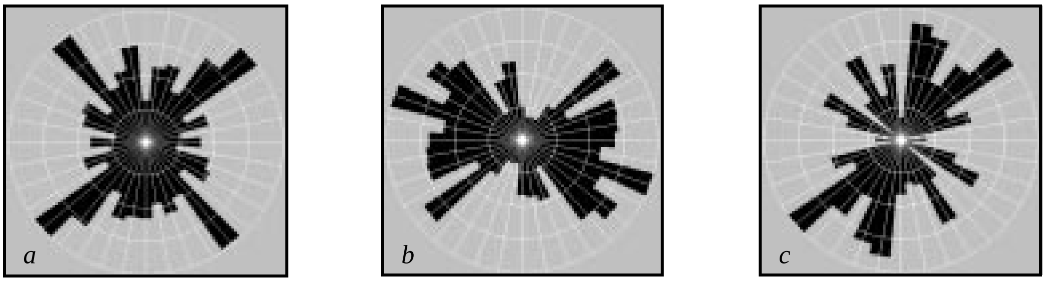
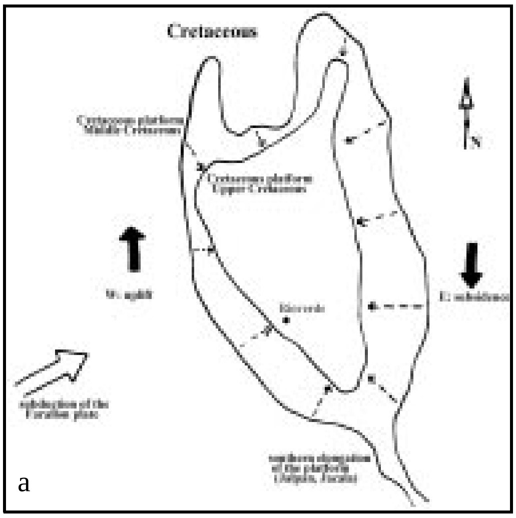


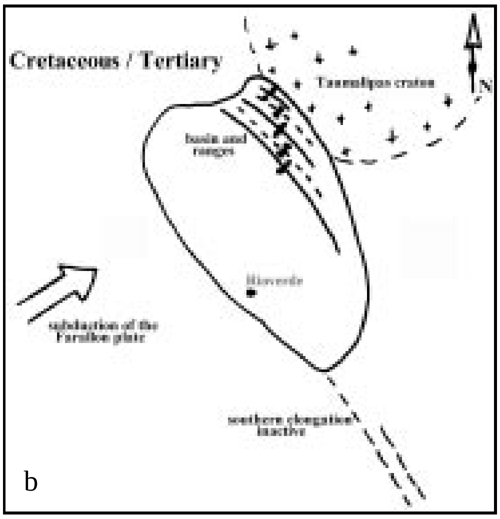
Fig. 80 Rose diagrams with weighted sectors, minimum length of considered structures 10 s = 300 m;
(a) for the whole basin (predominancy of NW-SE and NE-SW striking structures),
(b) for the NW part of the basin (Cretaceous El Doctor limestones, predominancy of NW-SE striking structures) and
(c) for the SW part of the basin (Tertiary rhyolithes, predominancy of NE-SW striking structures)

4.4. Geological Model

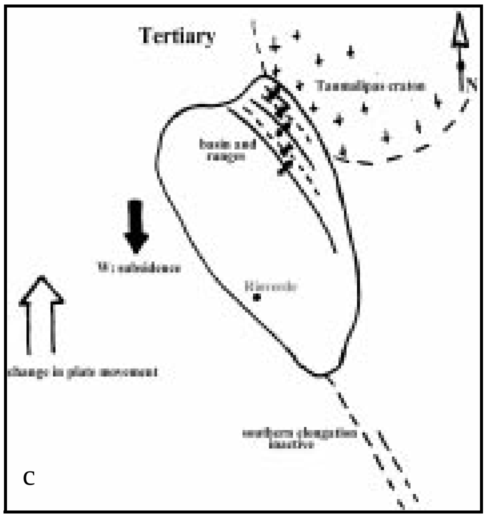
As synthesis of all the above mentioned geological, geophysical and tectonical analysis and interpretations a model for the basin´s development was reconstructed. Due to the low data density the model is simplified and maybe even wrong in some aspects, but it should serve as conclusion of the work done and show the need of further detailed investigations to confirm or disprove the following model.

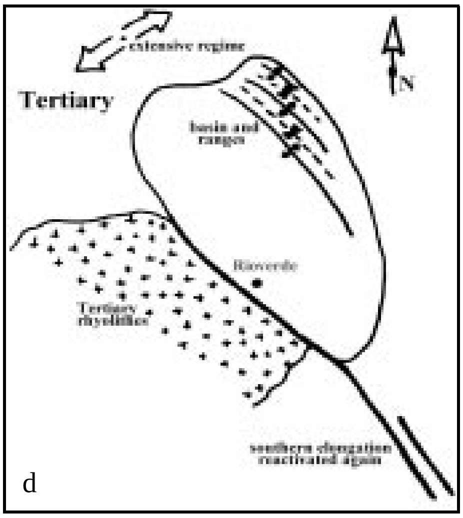
The oldest known and most important structure for the Rioverde basin is the Cretaceous carbonate platform (Fig.10). During Cretaceous it decreased in size and it´s southern elongation towards Jalpan and Jacala was cut off and became inactive (Fig.81a).





Due to tectonic forces related to the subduction of the Farallon plate at the end of Cretaceous to the beginning of Tertiary the platform´s western part was subject to uplift, while the eastern part was subsiding. The compressive forces from the SW deformed the limestones, that were folded in basins and ranges against the craton of Taumalipas acting as a counter weight in the northeast (Fig.81b). Today this basin and range province forms the northeastern border of the Rioverde basin. A change in plate movement caused the former uplifting western part to subside too, whole rock stacks were sliding and deforming, maybe also the basins and ranges (Fig.81c).





The following extensive regime enabled acid volcanic extrusions on the western margin of the former carbonate platform. Probably at the same time the old southern elongation of this platform was reactivated again (Fig.81d)

Fig. 81 a-d Development of the Rioverde area on the carbonate platform from Cretaceous to Tertiary

With the available data it is difficult to determine if the Rioverde basin presents a graben, a halfgraben or a pull-apart basin structure. In Fig.82 the graben concept is presented. With the idea of different tectonic scales it could explain the hugh vertical differences in short horizontal distances in the geophysical profile El Jabali as well as the asymmetrical depth of the basin filling (Fig.83). No evidences were found for a displacement of structures indicating a pull-apart basin. The idea of a halfgraben with a listric fault in the west gently dipping to the east and a antithetic flexure dipping to the basin´s interior from the east was pursued. In the model it looks irrealistic since the altitude superelevation makes it look like an almost 90° angle, but calculating the necessary flexure angle in the southeastern part it comes to be about 1:12 (from 1200 masl (hill El Chichote) to 550 masl (deepest point in the basin) over 8000 m horizontal distance). But limestone layers outcropping on hills in the basin´s eastern part showing a dipping towards the east (outcrop #11) contradict this flexure theory.

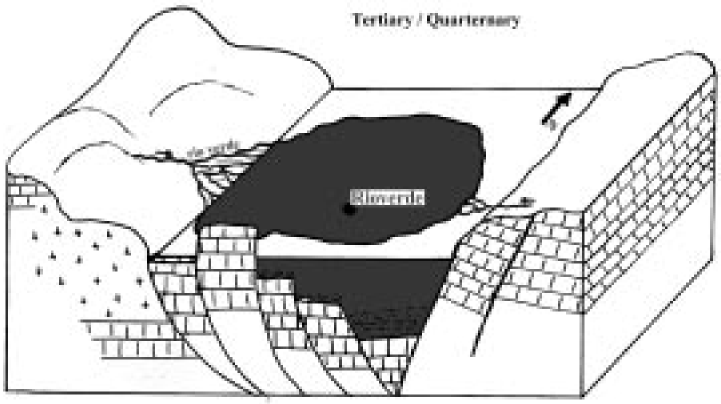
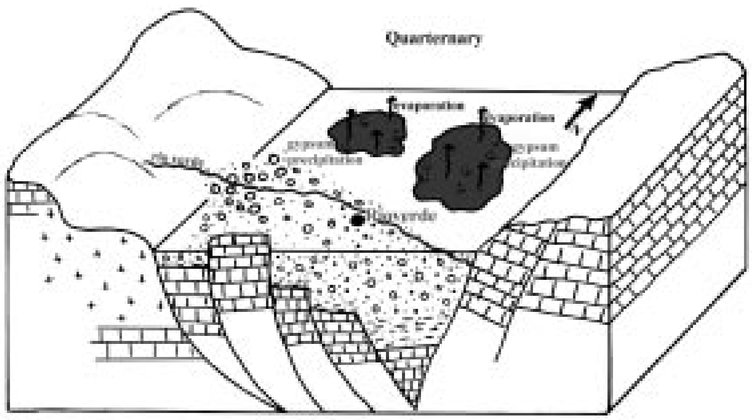


Fig. 82 Quarternary development of the Rioverde area
a) *Early Quarternary: Formation of an asymmetrical drainageless graben with lacustrine environment*

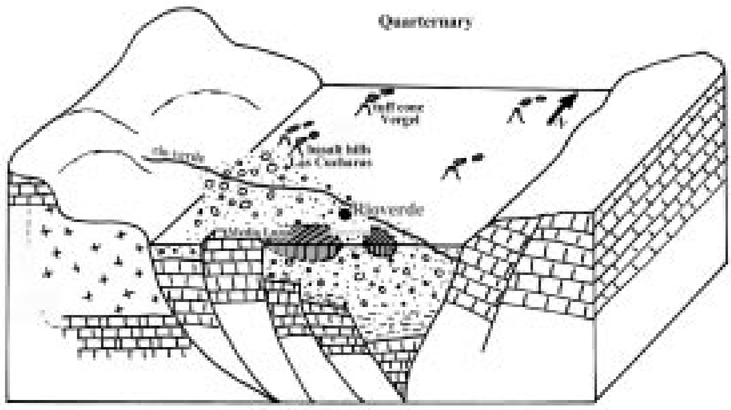
The sudden subsidence of the area around Rioverde created a drainageless depression with the river rio verde forming a delta on it´s western margin (Fig.82a). This delta was detected both on false color satellite images, especially in the combination of the channels 6-5-7 (digital tntmips atlas, file topography, Landsat_ images) as well as on the interpretation map of potential land use (digital tntmips atlas, file topography, potential_use).

The conglomerates of outcrop 7 seem to indicate that there has even been a drainage from the east carrying limestone material downslope that was cemented with calcareous cement in the basin. Probably at this time almost the whole area showed lacustrine environment, proved by thick chalk layers.

In very short time the river build up it´s deltaic fan towards the east, replacing the lake except for small water filled depressions north of Rioverde (Fig.82b). Under the semiaride climatic conditions evaporation began causing the precipitation of gypsum in these remaining lacustrine environments. The river found it´s way again through the basin and continued in it´s supposed old riverbed. The asymmetry of the river sediment distribution towards the south could be just due to morphological preferences (filling of the deeper depressions in the south), but it could also indicate that there has been a drainage towards the southern elongation for a short time with symmetric sedimentation to both sides of the drain. The profile Las Magdalenas may confirm this with the interpreted shift of the riverbed to the north.



b) *Middle Quarternary: Basin filling with lacustrine and fluvial sediments; gypsum precipitation through evaporation from the remaining lakes*



***c)** Late Quarternary: Basaltic volcanism; youngest sediment precipitation: travertine around karst springs*

After the river took it´s supposed old riverbed again and the lakes disappeared basaltic volcanism started, intruding in lacustrine sediments (well No.143, P1 and P3) (Fig.82c). The tuff cone Vergel is also supposed to belong to this origin. Composited rocks of chalk and tuff fragments seem to indicate the intrusion of the tuff cone in the lacustrine frame. The youngest deposition in the basin are the travertine formations in the vicinity of the karst springs in the south.

Fig.83 shows the modelled basin depth, Fig.84 the distribution of the Quarternary sediments in the basin resulting from the above described basin development and Fig.85 the recent structural situation.

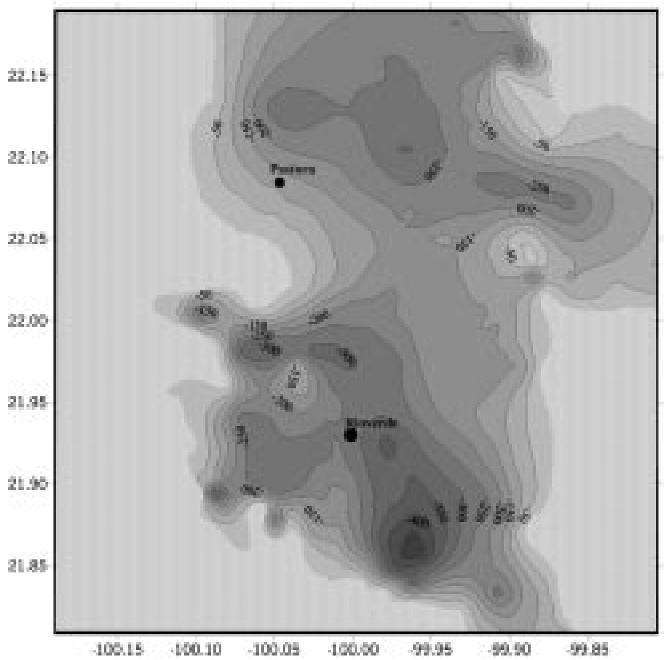


Fig. 83 Modelled depth of the basin´s filling (program: Surfer; gridding method: Kriging with linear variogram; dotted area outside = basin´s limits)

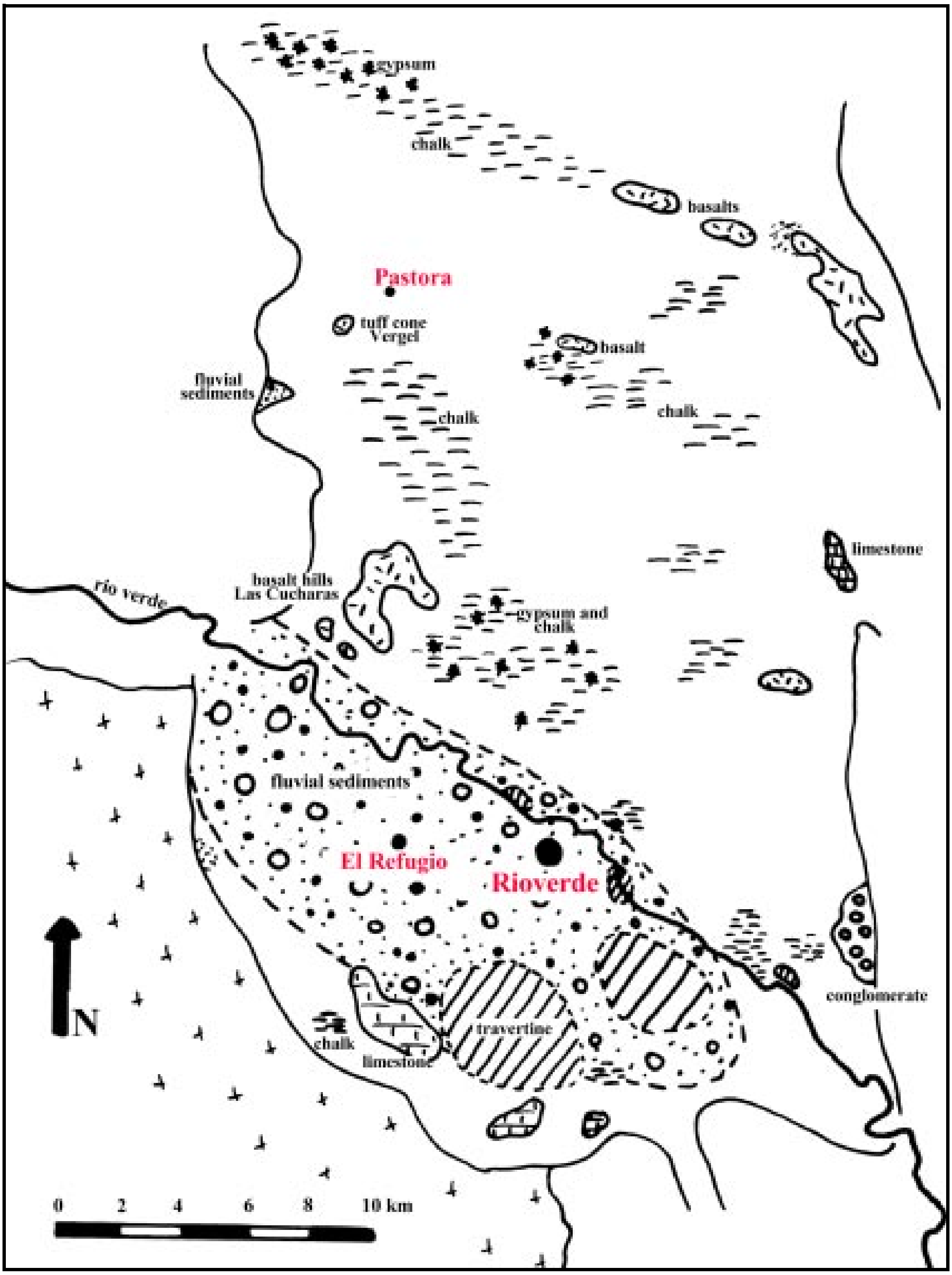


Fig. 84 Distribution of Quarternary sediments in the Rioverde basin

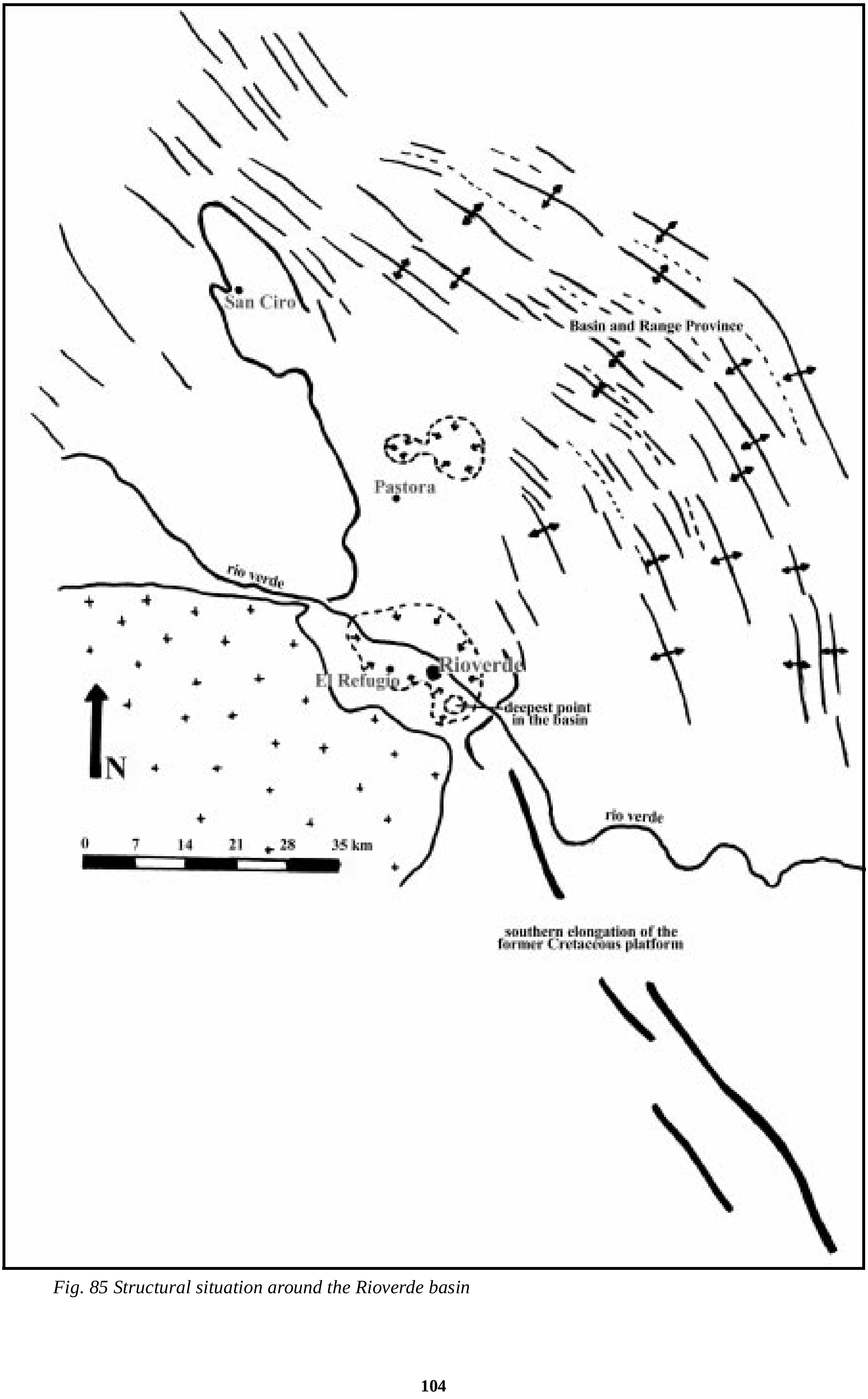


Fig. 85 Structural situation around the Rioverde basin

5. INTERPRETATION - HYDROGEOLOGY

5.1. Hydrology

5.1.1. Natural hydrological cycle

5.1.1.1. Groundwater recharge

Typical for a semiarid area with limited precipitation groundwater recharge *in the Rioverde basin itself* is low and bound to certain seasons. App.No.19 shows that the potential evapotranspiration (ETP) of all 5 climate stations in the basin was always significantly higher (2.4 times (El Huizachal) to 4.1 times (Pastora)) than the precipitation. Actual evapotranspiration (ETA) calculated according to Coutagne equation (chapter 3.2.1) almost equaled precipitation (97-99.9%). Therefore only an average of 5.3 - 13.05 mm/a remained for groundwater recharge in the basin, provided that surface runoff that couldn´t be quantified is negligible. Maximum water surplus occurs during the main rain season in September (1.17 - 3.67 mm/month), while during the whole dry season and especially at the end of it there is little to no surplus at all (February (March) 0 - 0.04 mm). Taking into consideration the high uncertainty of the ETA calculations it is only possible to state that the groundwater recharge <u>in</u> the basin is very low, maybe even negative in the dry season while there maybe some minor recharge during the rain season.

The major groundwater recharge is supposed to come from the *Sierra* west and northwest of the basin. The superficial / subterranean catchment areas outside the basin cover approximately

- (1) 11,122 km^2 (rio verde catchment area)
- (1a) 1,344 km^2 (1st confluent to rio verde)
- (1b) 1,353 km^2 (2nd confluent to rio verde)
- (2a) 3,920 km^2 (northwest of Pastora)
- (2b) 2,255 km^2 (north of Pastora)

(Fig.86 and digital tntmips atlas [file hydrology, watersheds])

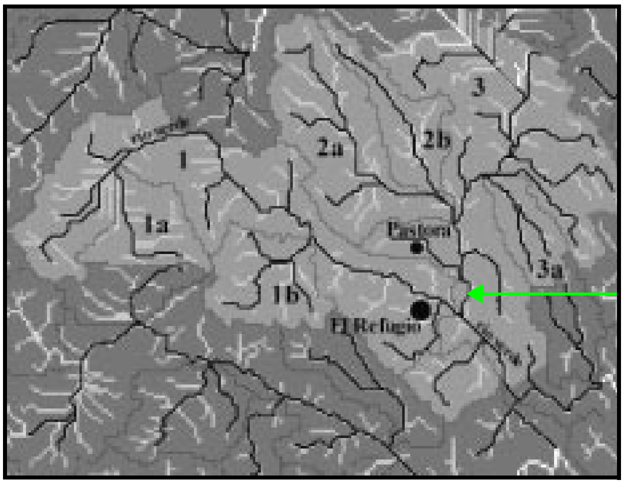


Fig. 86 Superficial (= subterranean) catchment areas (light gray) mainly west and northwest of the sampling sites El Refugio and Pastora (red = catchment boundaries, blue = potential drains), green arrow = burried river, see text

The calculation of the northern limits of catchment area No.3 showed some uncertainties because there are no significant morphological differences in this area (the basin´s northern border extends much further to the north) at least in the 1 km DEM. Using the 50 m DEM would probably give more reliable results. However since water from the northeastern part is not regarded to have major influence on the wells from Pastora area catchment area No.3 was neglected.

The river that conducts water from the catchment areas 2 and 3 in the north to the rio verde in the south (indicated by the green arrow in Fig.86) was not detected in the field. However false color images as well as prinicipal component analysis using all 7 channels from the Landsat scene 1986 indicate that there has been a river there in former times, draining the northern part of the basin (digital tntmips atlas [topography, landsat_images]).

According to the calculations described in chapter 3.2.1 the average groundwater recharge rates for these areas are:

- (1) 8.0 mm/(a*km^2) = 2.82 m^3/s (rio verde catchment area)
- (1a) 17.4 mm/(a*km^2) = 0.74 m^3/s (1st confluent to rio verde)
- (1b) 18.7 mm/(a*km^2) = 0.80 m^3/s (2nd confluent to rio verde)
- (2a) 7.3 mm/(a*km^2) = 0.91 m^3/s (northwest of Pastora)
- (2b) 4.8 mm/(a*km^2) = 0.35 m^3/s (north of Pastora)

This is a total amount of 4.36 m^3/s for El Refugio area and about a quarter of this (1.26 m^3/s) for Pastora area. It is amazing but the amount of recharge for El Refugio area equals exactly the average yield of the karst spring Media Luna. Of course this accuracy is an artefact considering all the uncertainties due to the necessity of extrapolation over a large area with no data at all simply by the relationship between altitude and temperature respectively precipitation, the semiempirical calculation of the actual evapotranspiration and the total ignoring of runoff in a montaneous area. However these calculations give an idea of the order of groundwater recharge and the ratio between the two study areas El Refugio and Pastora.

5.1.1.2. Hydrogeological settings

Fig.87, Fig.88 and Fig.89 show contour maps of the groundwater tables in the El Refugio area from 1972 to 1999. The groundwater flow direction is identical in all 6 maps from the Sierra in the west to the basin´s center in the east, showing that the river rio verde acts as the main drain for the aquifers.

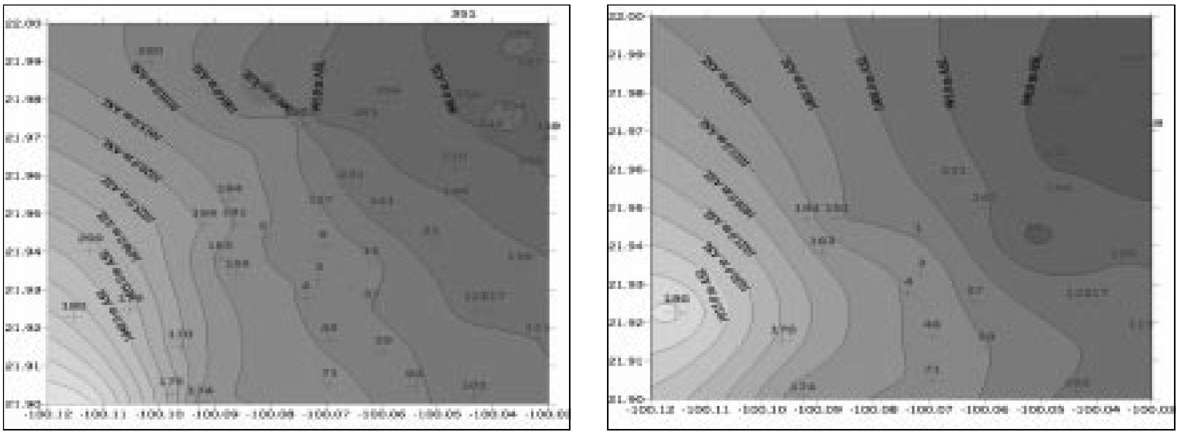


Fig. 87 Contour maps of the groundwater tables in El Refugio 1972 (left) and 1973 (right) (dark blue = deep, light gray = high) [Program surfer32; method Kriging with linear variogram]

The groundwater table data from previous projects contained no distinction between different aquifers. But combining the results from the geological reconstruction of the depth of the Quarternary basin fill (Fig.83) with the groundwater tables determined during the field trip in 1999 (App.No.22) it is obvious that the wells in El Refugio tap both the Cretaceous karst aquifer and the Quarternary aquifer. While the numerous shallow irrigation water wells are orientated to the unconfined Quarternary aquifer, some of Rioverde´s drinking water wells fully penetrate the Quarternary sediments and withdraw water from the Cretaceous karst aquifer (Tab.15). Further differentiation of the Quarternary aquifer was not possible with the avaiblable data.

Tab. 15 Selected wells for Rioverde´s drinking water supply - assumed to tap water from a confined Cretaceous karst aquifer

	depth of Quarternary filling [m]	casing [m]	well depth [m]	altitude [masl]	GW drawdown dynamic / static [m]	GW table dynamic / static [masl]	Δ static-dynamic level [m]
PSM	0-50	0-73	172	1030	72 / 21.6	958 / 1008.4	50.4
P16	50	0-78	130	1027	21.31 / 16.4	1005.7 / 1010.6	4.9
P17	50-100	0-87	170	1024	65 / 26.6	959 / 997.4	38.4
PSD (old)	100		180	1023	static: 36.4	986.6	
PSD	100	0-68	200	1023	57.5 / 44	965.5 / 979	13.5

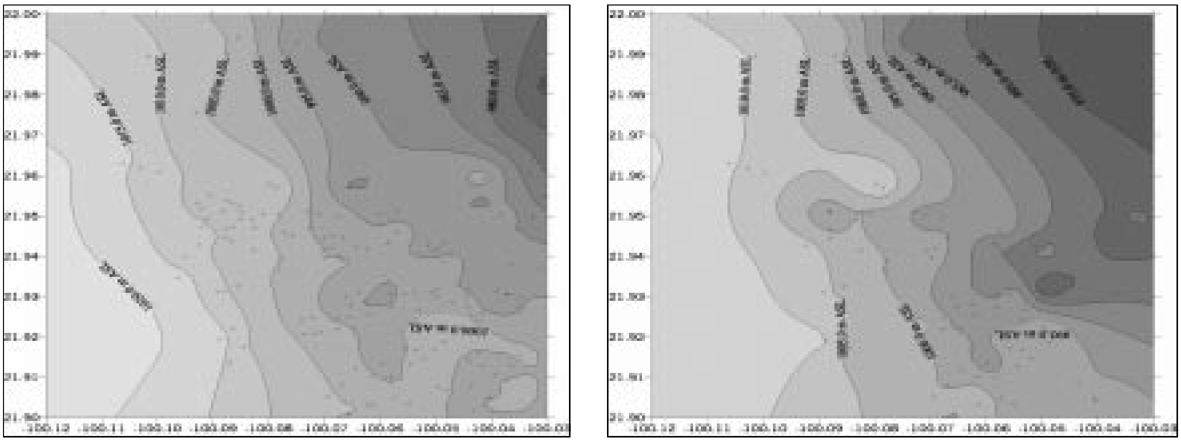


Fig. 88 Contour maps of the groundwater tables in El Refugio 1980: static (left) and dynamic level (right) (dark blue = deep, light gray = high) [Program surfer32; method Kriging with linear variogram]

Data from 1980 covering only the shallow irrigation water wells show almost identical contour maps for the static and dynamic groundwater levels (Fig.88), in average the difference is about 5m. In the deeper drinking water wells constructed after 1980 (P3 1981, P9 1982, P12 1983, P16 1984, P17 1984, PSD (old) 1990, PSD (new) 1999) hugh differences between static and dynamic levels occur (5-50 m Tab.15). This may indicate that the Cretaceous aquifer is confined. According to the higher static water levels in the drinking water wells the potential level of the confined Cretaceous aquifer seems to be slightly higher than the Quarternary groundwater table, at least at the basin´s margins, maybe converging to the basin´s center (Fig.112).

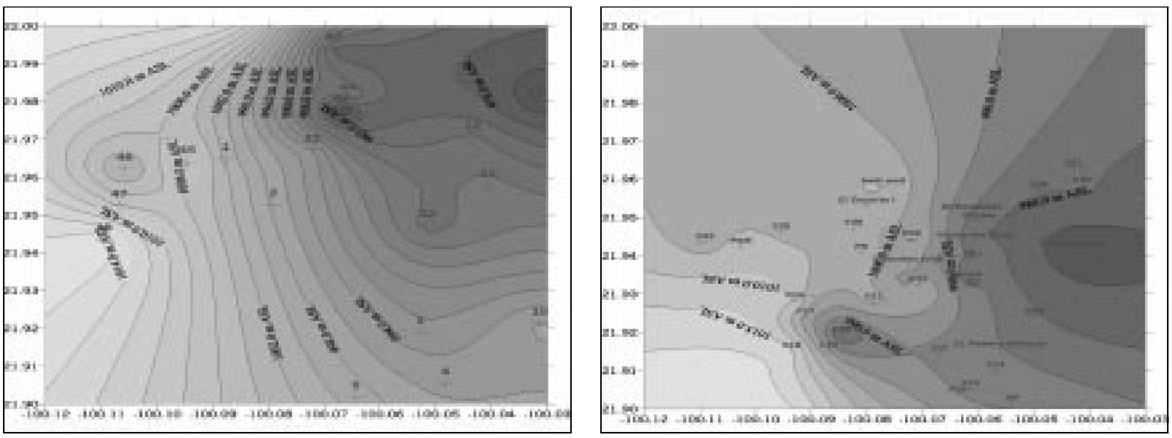


Fig. 89 Contour maps of the groundwater tables in El Refugio 1997 (left) and 1999 (right) (dark blue = deep, light gray = high) [Program surfer32; method Kriging with linear variogram]

In Pastora area the groundwater flow direction is from the east to the west, opposite to the one in El Refugio. This could be explained by the hydraulic activity of the western fault zone with higher kf-values than the fine sand and chalk layers in the basin. Most wells around Pastora only penetrate the upper part of the Quarternary sediments and show little variation in their groundwater tables neither from static to dynamic stage nor between different wells (994 - 1001 masl). The aquifer is supposed to be unconfined with lower kf-values than the one(s) in El Refugio corresponding to the deposited fine sand and chalk layers.

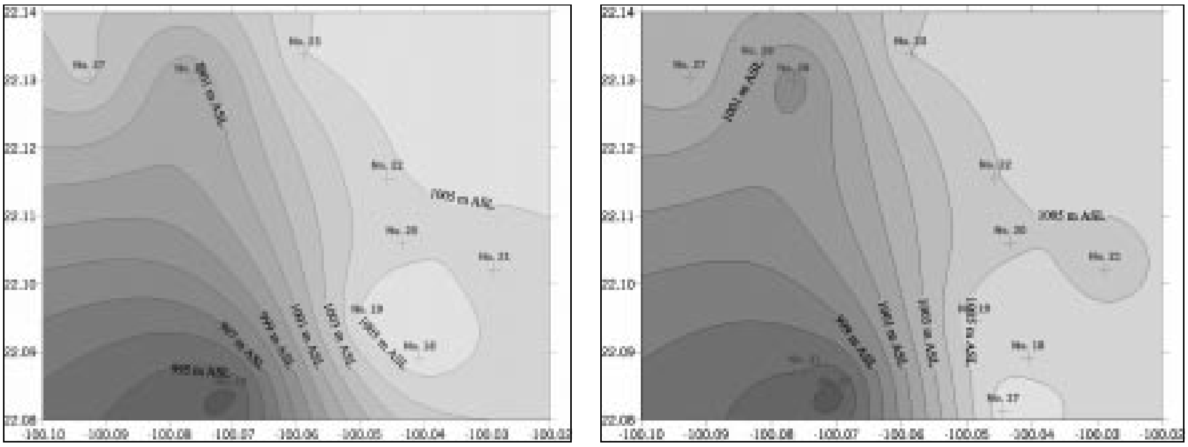


Fig. 90 Contour maps of the groundwater tables in Pastora 1996 (left) and 1998 (right) (dark blue = deep, light gray = high) [Program surfer32; method Kriging with linear variogram]

Fig.91 (left) shows upconing around the wells Rancho #13 and Santo Domingo. Both wells with depths of 150 m respectively 50 m probably penetrate the about 50 m thick Quarternary sediments with the screens in both Quarternary and Cretaceous aquifers. They have the highest static water levels with 1005 respectively 1003 masl, affected by the higher potential of the confined deeper aquifer.

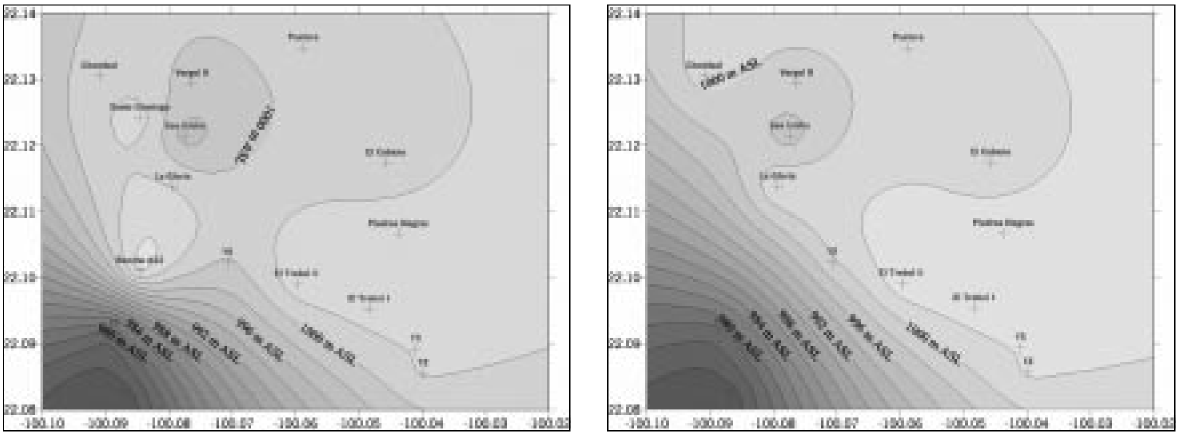


Fig. 91 Contour maps of the groundwater tables in Pastora 1999; all determined wells (left); without the wells Rancho #13 and Santo Domingo which are influenced by Cretaceous aquifer (right) (dark blue = deep, light gray = high) [Program surfer32; method Kriging with linear variogram]

Fig.92 presents a summarizing sketch of the hydrogeological settings in El Refugio and Pastora (see also chapter 5.2.2.3 and Fig.112).

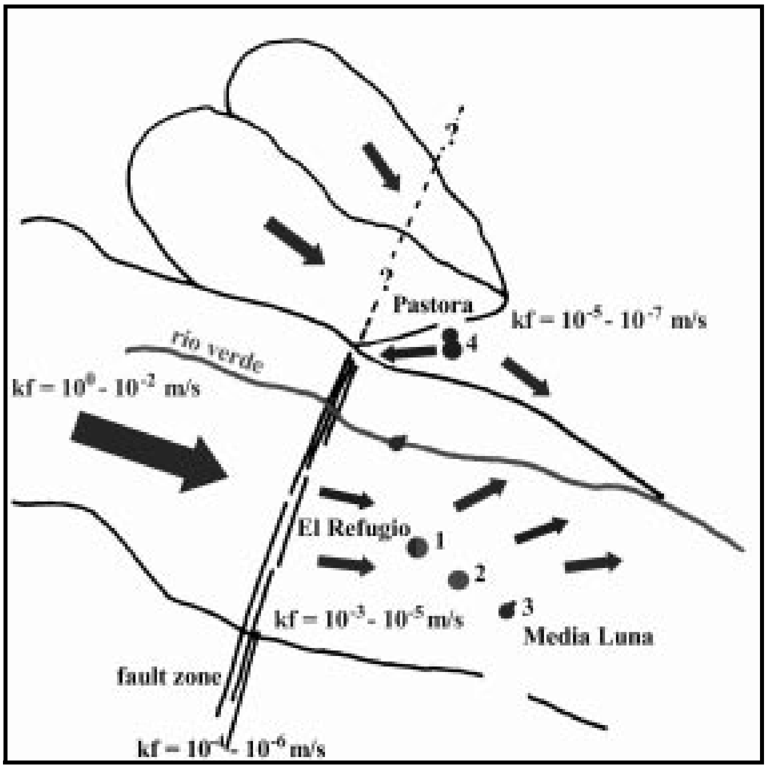


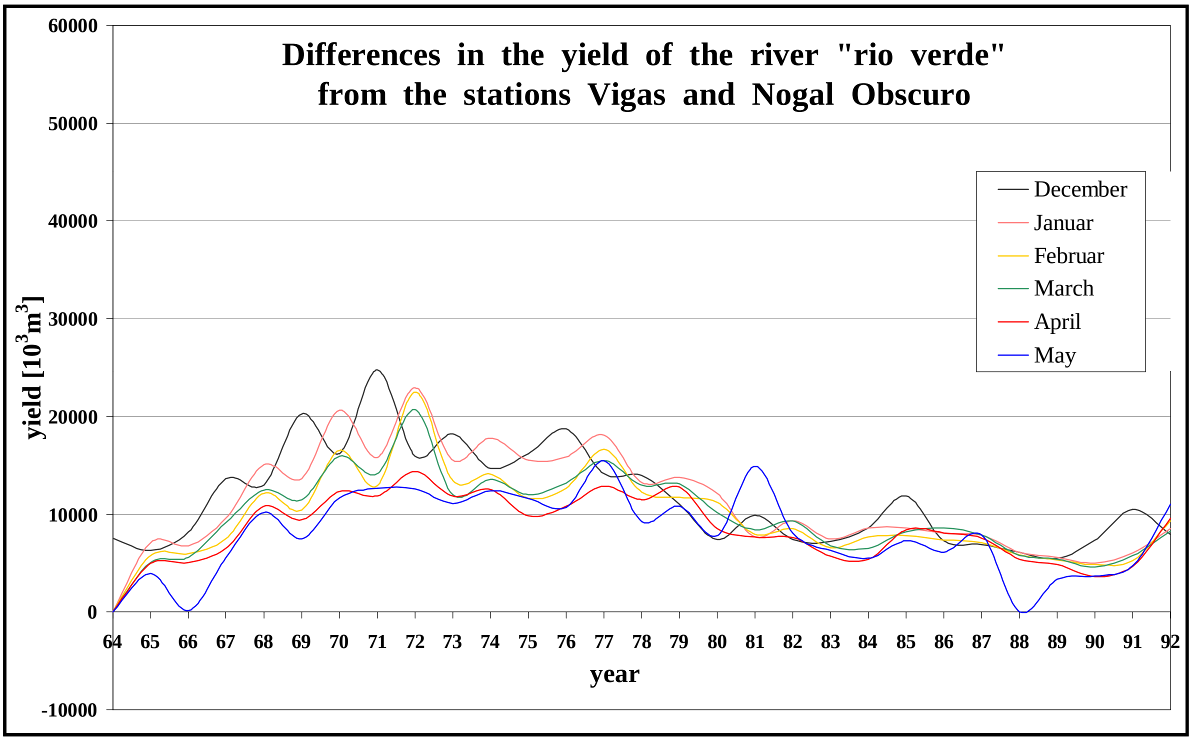
Fig. 92 Sketch of the hydrogeological settings in the southern part of the Rioverde basin (not to scale; red arrows: groundwater flow direction in the Cretaceous aquifer, blue arrows: groundwater flow direction in the Quarternary aquifer, numbers 1-4 correspond to the cluster groups 1&2 El Refugio, 3 Media Luna, 4 Pastora; colors of the circles indicate the aquifer taped, blue = tap Quarternary aquifer, red = tap Cretaceous aquifer, blue/red = tap both aquifers)

5.1.2. Man made changes in the hydrogeological settings

5.1.2.1. Surface water

To visualize man made effects on the surface water changes in the yield of the rio verde were examined. The yield of the river is determined at the inlet (Nogal Obscuro) and at the outlet (Vigas) of the basin. The actual river spring is located in the basin garantueeing the river´s base flow. Fig.93 shows that beyond annual variations there is a general decreasing trend in the differences Vigas - Nogal Obscuro from the early 1970s until today. Since this is not owed to an increase of the water from the Sierra it can only result from less water at the outlet, respectively higher consumption of the river water for irrigation in the basin. As Fig.93 shows during some months already today there are almost no more differences between inlet and outlet, that means all the water from the base flow of the river is used up.

The increase of the difference between 1964-1970 may be caused by the construction of the main irrigation channel from Media Luna to the north. In former times it discharged all the surplus water and irrigation return flow to the rio verde. Nowadays the irrigation water is conducted further to the north with a siphon underneath the river.



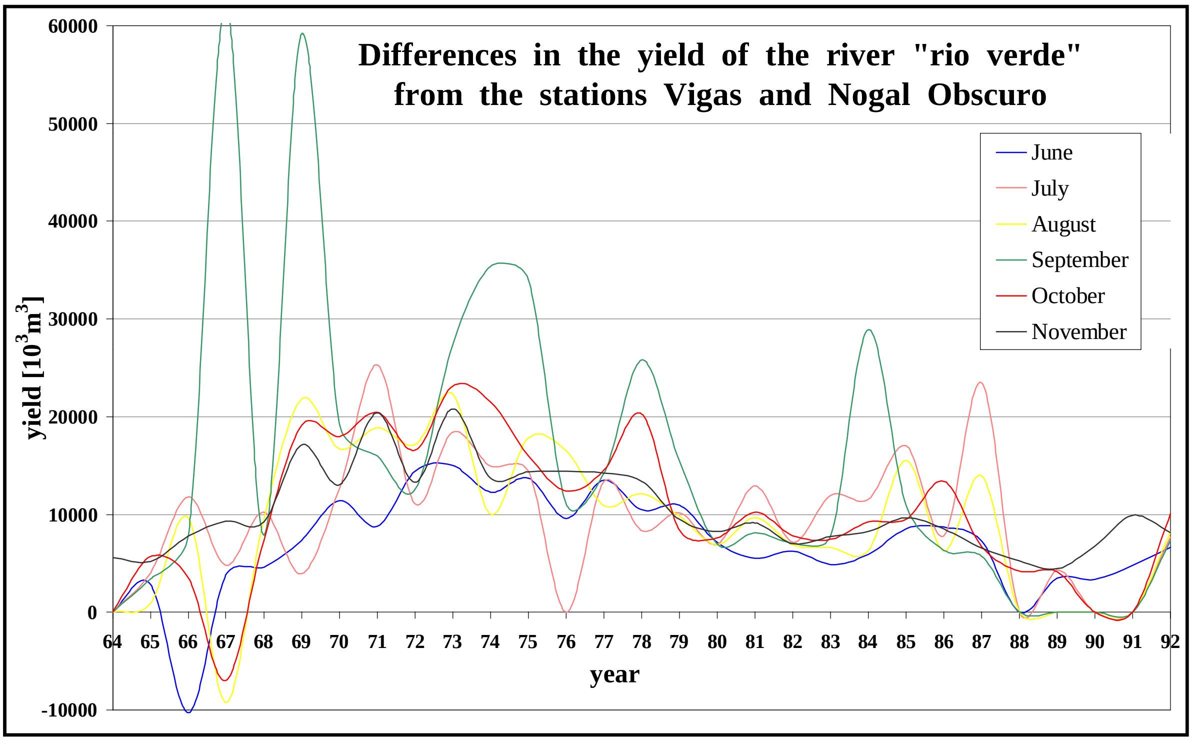


Fig. 93 Differences in the monthly yields of the rio verde between the stations Nogal Obscuro on the eastern and Vigas on the western margin of the basin show a slightly decreasing trend from 1964-1992, indicating the more intensive use of irrigation water and the consequent less contribution to the river yield (top: December - May, bottom: June - November; data App.No.4)

5.1.2.2. Groundwater

In Pastora no man made effects on the development of the groundwater tables were discovered from 1972 to 1999. The variations in the groundwater tables were less than 1m between the following years in the following wells (data App.No.22):

- from 1972-1980 in the wells 382, 395, 404, 408, 409, 412, 430,
- from 1980-1998 in the well 18 (respectively 923, numbering from 1980),
- from 1986-1998 in the wells 17, 21, 22,
- from 1986-1999 in the well 28 / Vergel II,
- from 1996-1998 in the wells 19, 23, 24, 27 and
- from 1996-1999 in the well 20 / Piedras Negras

Contrary to Pastora the development of the groundwater tables in El Refugio reflects the intensive use for drinking water supply and irrigation. Taking 1972 as reference year the average drawdown until 1973 was about -2 to -4 m, until 1980 already -5 to -10 m, around single wells -15 m, and until 1997 -10 to -15 m over a large area (Fig.94). The development from 1972 to 1999 shows that especially in the most heavily exploited center drawdown maybe up to -20 m, especially PSD that originally taps water from the Cretaceous aquifer creates a sharp depression cone of more than -25 m, causing an additional ground-water withdraw from the Quarternary aquifer and locally changing the groundwater flow direction.

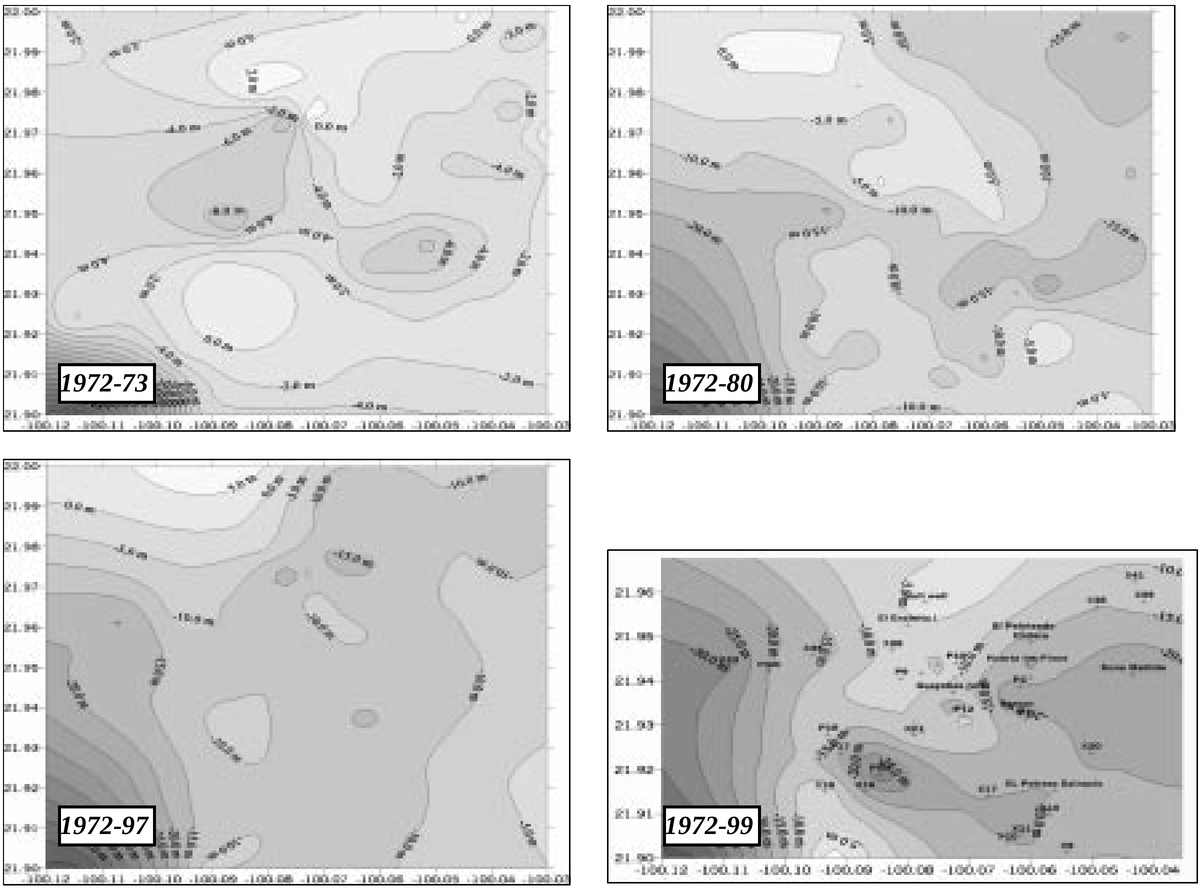


Fig. 94 Contour maps of the development of the groundwater tables in El Refugio 1973-72 (upper left), 1980-72 (upper right), 1997-72 (lower left) and 1999-72 (lower right) (red = max. drawdown, light yellow = min. drawdown) [Program surfer32; method Kriging with linear variogram]

One fact that also proves quite obviously longterm drawdown of the local phreatic level but was never mentioned before in any study is the fact that in the area between El Refugio and El Jabali many wells (10 out of 12 examined) have been shallow (6-13m) dug wells in which later on deeper vertical turbine pump wells have been drilled (Fig.95).

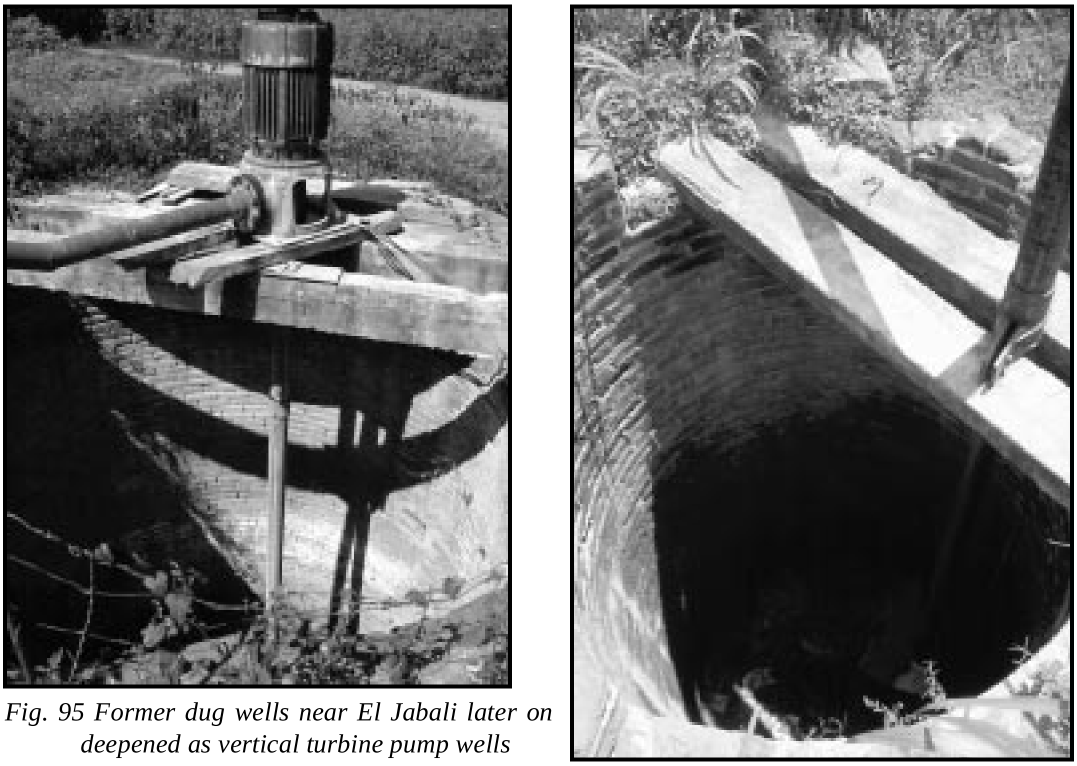


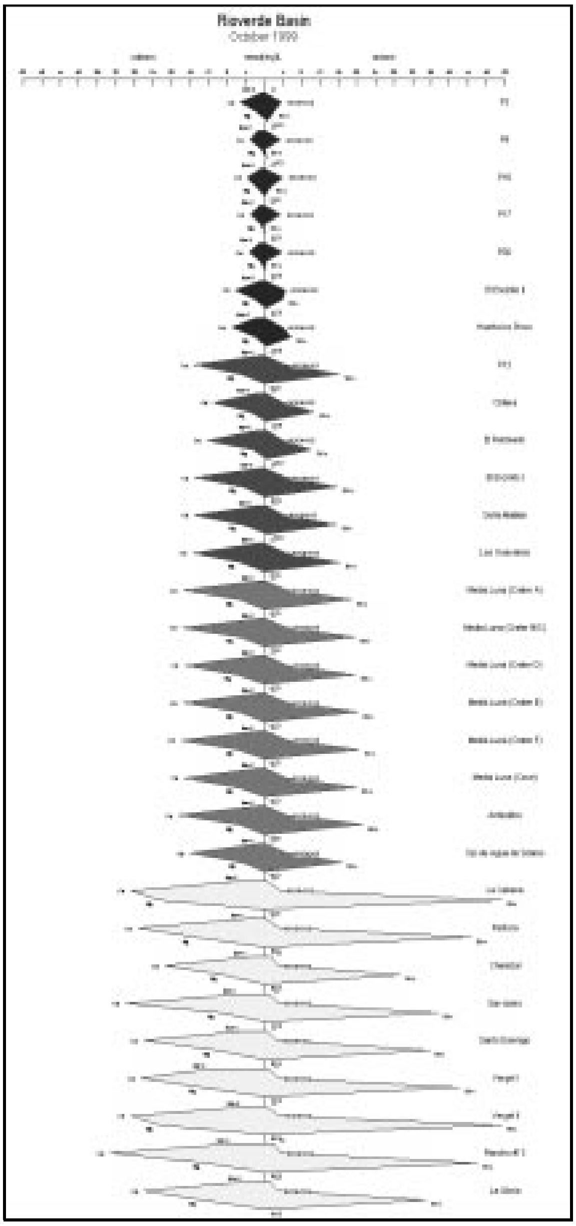
Fig. 95 Former dug wells near El Jabali later on deepened as vertical turbine pump wells

Today the water table in these wells is 4 to 15(!) m below the bottom of the dug wells. This is consistent to the fact that a bit further to the south the large wetlands around Media Luna are strongly shrank in size and the lagoon El Jabali west of the village El Jabali today is totally dry and cultivated land (Fig.20). Only about 3 km further to the west near the village La Loma two dug wells of approximately 10-12 m still have water (water table 4.5 m) and only one former dug well has been found in the area north of the line El Refugio-San Diego (well Dona Matilde, Appendix - mapping, well and spring description). This seems to indicate a quite local drawdown of the water table in the southern part.

5.2. Hydrogeochemistry

5.2.1. Hydrogeochemical results for the different cluster groups

The following subdivision of the sampled wells and springs is based on the cluster analysis described in chapter 3.3.3. Stiff diagrams (Fig.96) and Piper diagrams (Fig.97) calculated for all chemical analysis from June and October serve to visualize the cluster membership and general chemical group characteristics.



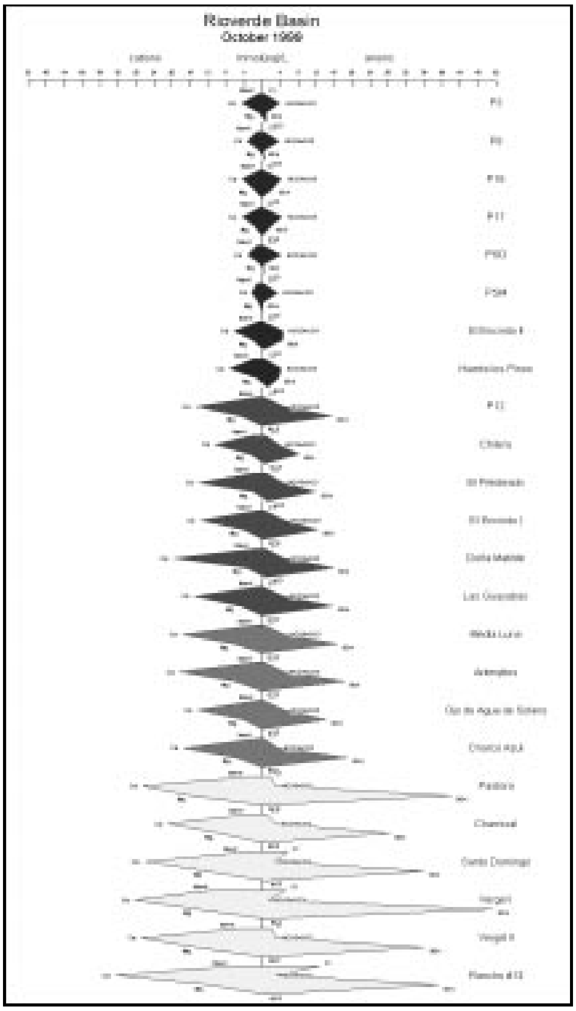


Fig. 96 Stiff-diagrams for all samples from June/July (left) and October (right) sampling; colors according to clusters (blue = group 1, red = group 2, green = group 3, yellow = group 4)

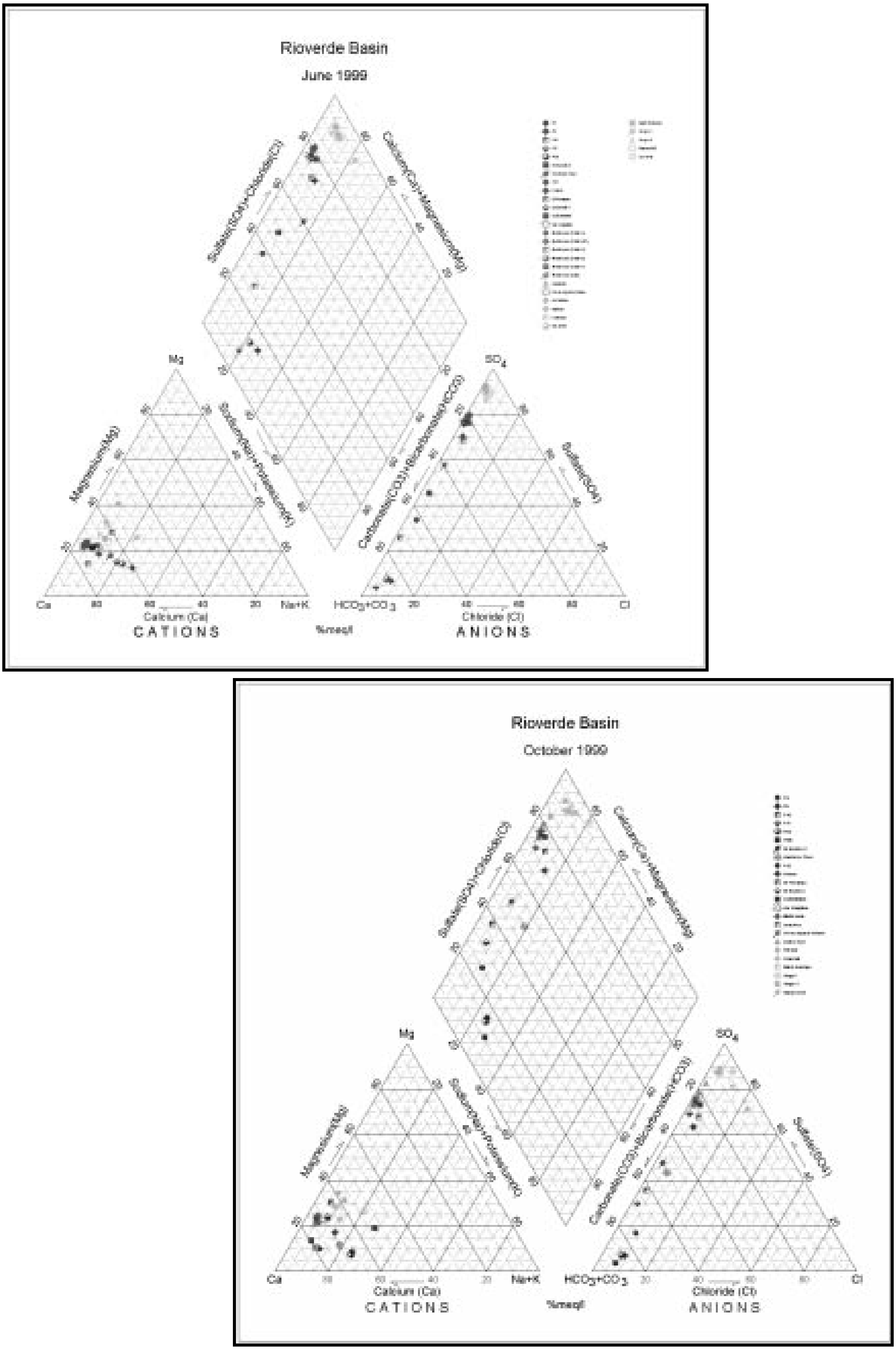


Fig. 97 Piper-diagrams for all samples from June/July (top) and October (above) sampling; colors according to clusters (blue = group 1, red = group 2, green = group 3, yellow = group 4)

5.2.1.1. Group (1) - El Refugio wells

members (8): P3, P9, P16, P17, PSD, PSM — water used as drinking water
El Encinito II, Huerta los Pinos — water used as irrigation water

<u>5.2.1.1.1 Characterization</u> --- **Ca-HCO_3 groundwater with low total mineralization**

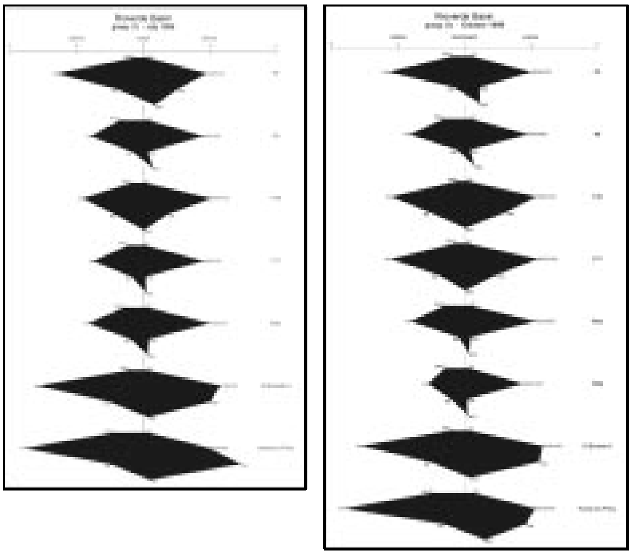


Fig. 98 Stiff diagrams group (1) (left: samples from June, right: samples from October)

Fig.96 shows that the wells belonging to cluster group (1) are the ones with the lowest conductivities (598 µS/cm (June) / 572 µS/cm (October)) and the lowest total mineralization. Average temperatures are 26.5°C (June) respectively 25°C (October).

The predominant ions are Ca and HCO_3. Due to the general low mineralization this group is the only one in which groundwater is slightly under-saturated with regard to calcite (∅ SI_{CaCO3} = -0.08) (App.No.32).

Unlike within the other clusters sulfate concentrations are low, only P16, El Encinito II and Huerta los Pinos plus P3 (June samples) respectively P17 (October samples) can be characterized as Ca-<u>HCO_3</u>-SO_4 types. But the corresponding mineral phases gypsum and anhydrite are far more under-saturated (∅ SI_{CaSO4}= -2.07, ∅ $SI_{CaSO4*2H2O}$ = -1.86) than in the other 3 groups.

The aquatic complexes that form in this group are consequently HCO_3-complexes predominating over SO_4-complexes contrary to the other 3 groups. The share of free ions is much higher than in the other groups due to the lower total mineralization (Fig.99, Fig.108).

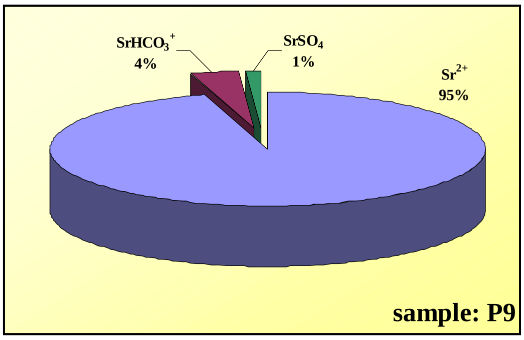
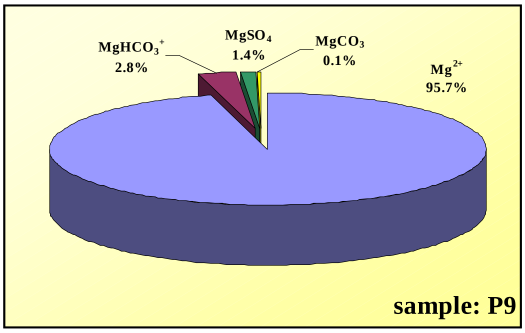
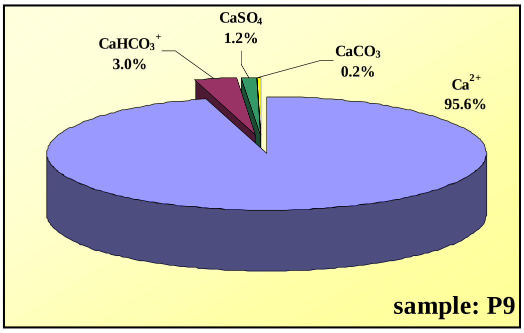


Fig. 99 Main species distribution for Sr, Mg and Ca - representative example P9





The concentrations of B, Co, Cu, F, Li, Ni, Sr are the lowest of all groups showing a general increase from group (1) to group (4). As and Se concentrations showed this same general trend in the June/July ICP-MS analysis. The October ICP-MS analysis however indicate a more local influence with positive correlation of As-Sb-Se-Tl-U (App.No.31), increased in P16 and Huerta los Pinos compared to the other cluster members. Locally increased are furthermore Cr (PSD, PSM, P16) and Zn (P16, P9).

Noticeable are general high concentrations of Ba, Nd and Pb, which show positive correlation with each other and negative correlation with the above mentioned elements As, B, Co, Cr, F, Li, Ni, Sb, Se, Sr, Tl and also Cl. Especially the increased Ba concentrations (80-170 µg/L compared to a natural average of 1-2 µg/L) seem to play a mayor role for the arsenic concentration in the groundwater. The groundwater is calculated to be super-saturated with regard to the mineral phase $Ba_3(AsO_4)_2$ in all groups and with a saturation index of 7.81 group (1) shows the highest super-saturation of all combined with the lowest average arsenic concentrations. This is consistent with the negative correlation of Ba and As. The sample PSD (Pozo San Diego) shows how effective this mechanism is. With a concentration of 158 µg/L Ba the saturation index is calculated to be +8.12, with 15.8 µg/L it is still +5.12 and with 1.58 µg/L +2.12. Only with a concentration of 0.158 µg/L (= 158 ng/L) the solution becomes under-saturated (SI = -0.88). This effectiveness is explained by the high solubility constant:

$$Ba_3(AsO_4)_2 = 3\ Ba^{2+} + 2\ AsO_4^{3-} \qquad \log K = -50.110 \text{ (database: PhreeqC, Wateq4F)}$$

The fact that $Ba_3(AsO_4)_2$ is super-saturated in the solution but not precipitated yet is probably owed to slow kinetics. Inspite of the high Ba concentrations $BaSO_4$ is under-saturated (SI = -0.08) due to the lack of sufficient SO_4.

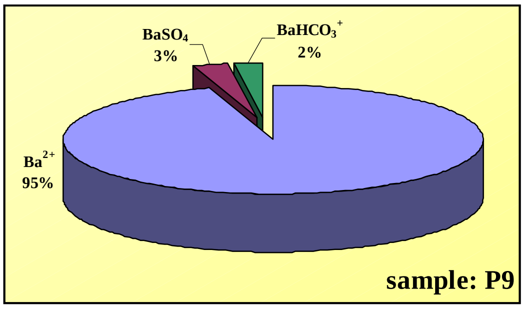


Fig. 100 Main species distribution for Ba - representative example P9

Even if some of the measured Ba concentrations slightly exceed the WHO standards of 100 µg/L, the risk of Ba is regarded as low since Barium ions in the solution are calculated to be mainly Ba^{2+}, easily sorbed by any cation exchanger like clay minerals. Only a minor part is bound as uncharged $BaSO_4$ complex (Fig.100).

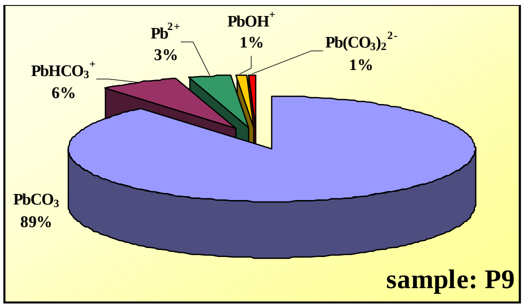


Fig. 101 Main species distribution for Pb - representative example P9

An eye should be kept on the Pb concentrations. Most of the wells plot well in the worldwide natural range of Ø 1.9 µg/L. P16 with 7.75 µg/L is still below the Mexican drinking water standard of 25 µg/L but is already slightly increased. The potential danger is that 89% of the lead occur as uncharged $PbCO_3$ complex which is not subject to any exchange or retention mechanisms and thus very mobile (Fig.101).

The high saturation indices for iron and aluminium compounds (App.No.32), that are found almost equally increased not only in this but also in the other 3 groups, are remarkable. Mean values for the 4 cluster groups are e.g. $SI_{Fe(OH)3}$ = 1.22-2.02, SI_{FeOOH} = 7.22-7.96, SI_{CuFeO2} = 11.73-13.06, $SI_{Al(OH)3}$ = 1.96-2.71, SI_{AlOOH} = 3.21-3.95. Since these iron and aluminium compounds would precipitate rather fast if they were super-saturated, the determined concentrations seem to be influenced by the sample technique. With a filtration of 200nm iron and especially aluminium colloids may pass the filter and be dissolved with adding of acid pretending increased concentrations of "free" ions.

No explanation was found for the super-saturation of many phosphate compounds like Fe**PO_4***$2H_2O$ (Ø SI = 0.09-0.65), Pb_5(**PO_4**)$_3$Cl (Ø SI = 0.11-1.34), Ca_5(**PO_4**)$_3$F (Ø SI = 1.40-2.64), $PbAl_3$(**PO_4**)$_2$ (Ø SI = 1.39-4.42) and especially FCO_3-**Apatite** (Ø SI = 11.9-15.98) in all 4 groups since these should precipitate rather fast.

Besides these general correspondences group (1) is the group that shows the most distinct internal differentiation (Fig.96, Fig.97). Especially the samples from Huerta los Pinos and El Encinito II cause doubt about the cluster membership with their increased conductivity, Ca and SO_4 concentration and saturation indices for gypsum ($SI_{CaSO4*2H2O}$ = -1.02 and -1.19) and calcite (SI_{CaCO3} = +0.1 and +0.04). But still these values are only about half of the respective values for the cluster group (2), justifying their membership to group (1).

Increased CO_2 concentrations for Huerta los Pinos in June (23.32 mg/L) couldn´t be confirmed with the second sampling in October (5.39 mg/L), increased Na concentrations were detected during both samplings for this well, additionally increased Cl concentrations in October. The wells P3, P16, El Encinito II, Huerta los Pinos (June) respectively P16, P17 and El Encinito II (October) show small Mg peaks (18-25 mg/L). NO_3 is increased only locally in P3, P9, El Encinito II, Huerta los Pinos.

5.2.1.1.2 Restrictions and limitations for water use

In June and October 1999 the following parameters exceeded drinking water standards in the sampled drinking water wells (Tab.16).

.

Tab. 16 Inorganic substances exceeding drinking water standards in the sampled drinking water wells in June and October 1999 (standards from the German TrinkwV 1990 and the Norma Mexicana 1994)

	P3	P9	P16	P17	PSD	PSM	TrinkwV / Norma Mexicana
June 1999							
temperature [°C]	26.3	---	28.5	26.1	25.9	n.d.	25 / no
Al [µg/L]	231.26	266.49	---	---	203.29		200 / 200
Fe [µg/L]	---	---	680.48	---	483.79		200 / 300
October 1999							
temperature [°C]	---	---	25.5	---	25.4	25.2	25 / no

Due to the general low mineralization in these wells there are no problems with increased calcium or sulfate concentrations. The only critical elements are Al, exceeding the standard at most by 130% (P9, P3, PSD), and Fe, exceeding Mexican standards by 161%, respectively 227% (P16, PSD).

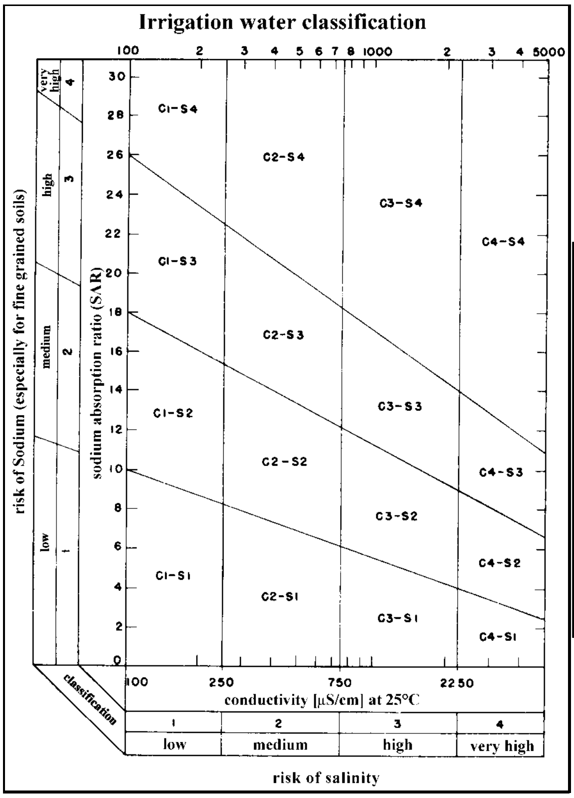
The screening for pesticides showed that some waters exceed maximum concentration levels (MCL) set by the EPA or the WHO, especially for α-HCH, heptachlor, aldrin, dieldrin, endrin and the sum of DDT, DDE and DDD (Tab.17). Contrary to the MCLs from WHO and EPA, that are set only for dedicated pesticides, the German drinking water standard (TrinkwV) is much stricter, stating that pesticides are man made and any occurence in groundwater is of concern. Therefore the MCL for single organic pesticides is 100 ng/L and 500 ng/L for the sum of all of them. Except for PSD all well waters exceed these strict standards.

As it was mentioned before these data are based on a single sampling campaign and enrichment done in the field. Thus the results have to be interpreted carefully and with some doubt. However the development is obvious: P3 and P9 the oldest wells (1981 and 1982) show the highest pesticides contamination, while in P16 and P17 (1984) only some pesticides exceed drinking water standards yet. The only well with (yet) almost no organic contamination is the well PSD which was just drilled in 1999.

Tab. 17 Pesticides exceeding drinking water standards in the sampled drinking water wells in July 1999 (concentrations in ng/L)

pesticides	**P3**	**P9**	**P16**	**P17**	**PSD**	drinking water limitations
α-HCH (GC-MS)	219	148				200 EPA
Heptachlor (GC-ECD)	173	233	108	21	---	30 WHO
Aldrin (GC-ECD)	176	244	114	53	7	30 WHO
Aldrin (GC-MS)	1052	856				30 WHO
Dieldrin (GC-ECD)	315	419	155	38	7	30 WHO
Endrin (GC-ECD)	263	---	89	60	---	2000 EPA
Σ DDT, DDD (GC-ECD)	2255	3447	1351	1467	155	2000 WHO
Σ DDT, DDD (GC-MS)	5696	3505				2000 WHO
sum of determined organochlorinated pesticides (GC-ECD)	4326	5872	2375	1808	169	500 (TrinkwV 1990)

Groundwater used for irrigation was classified according to the proposes from US SALINITY LABORATORY STAFF (1954) considering the risk of salinity (by conductivity) and the risk of sodium (by SAR = sodium absorption ratio, Eq.4). High sodium concentrations present problems for the pH and the soil texture, especially in fine grained or clayey soils that are difficult to drain.



$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}} \qquad \textit{Eq. (4)}$$

with Na, Ca, Mg in mmol(eq)/L

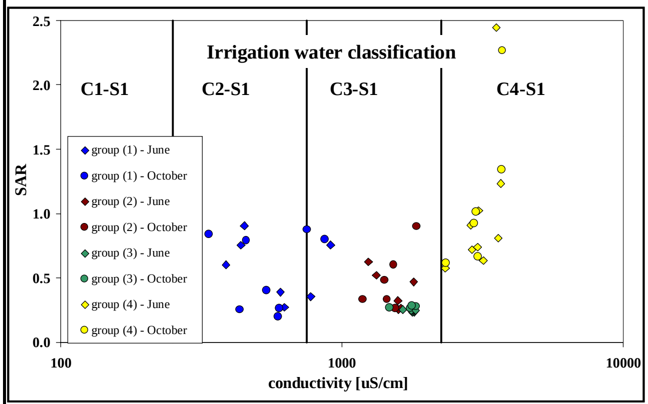


Fig. 102 Classification scheme for irrigation waters (US SALINITY LABORATORY STAFF 1954) (left) and magnified the classification-plot of the sampled wells in El Refugio and Pastora area (above)

Fig.102 visualizes that all the samples present low risks for irrigation use considering sodium and the consequent pH and soil texture problems (class S1). With this low risk of sodium water can be used for irrigation under almost all conditions without yield decrease. Up to 50% yield decrease may occur at 4-10 mS/cm for tomatoes, 6-7 mS/cm for oranges, lemons and avocados and 6-10 mS/cm for mais (WITHERS, VIPOND & LECHER 1978).

Most of the members of group (1) plot in the C2-S1 field with medium risk of salinity. The samples El Encinito II and Huerta los Pinos present medium to high risk of salinity and may present problems on clayey soils with low permeability.

Lithium and boron concentrations are also decisive for the quality of irrigation water. Lithium concentrations of 0.06-1 mg/L may already be dangerous for sensitive plants like citrus fruits. While in the June samples average Li concentrations were determined to be about 0.01 to 0.04 mg/L, they were 0.4 mg/L in average and 0.87 mg/L for the well Huerta los Pinos in the October samples. Boron, which may be toxic for citrus fruits in concentrations of more than 1 mg/L, was determined to be 0.014 to 0.04 mg/L in the June samples and 0.45, respectively 0.53 mg/L for the wells P16 and P3 in October.

5.2.1.2. Group (2) - El Refugio wells

members (6): P12, Chilera — water used as drinking water
El Peloteado, El Encinito I, Las Guayabas, Dona Matilde — water used as irrigation water

5.2.1.2.1 Characterization **--- Ca-SO_4 groundwater with medium total mineralization**

Groundwaters of cluster group (2) are characterized as Ca-SO_4 type with more or less equal concentrations of SO_4 and Ca (Ca > SO_4 in the wells El Peloteado and Chilera). Calcite concentrations reach equilibrium except for a slight super-saturation in the well Dona Matilde, while gypsum is under-saturated, though higher than in group (1) (∅ $SI_{CaSO4*2H2O}$ = -0.53) (App.No.32).

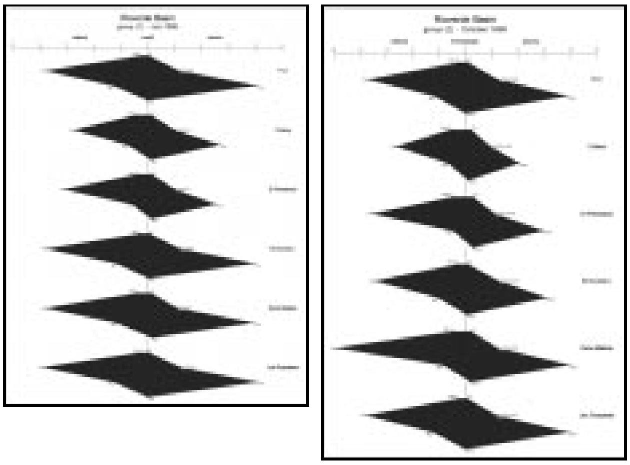


Fig. 103 Stiff diagrams group (2) (left: samples from June, right: samples from October)

According to temperature (27.2°C (June) / 26.6°C (October)) and total mineralization / conductivity (1525 µS/cm (June) / 1494 µS/cm (October)) group (2) seems to show influences both like the Ca-HCO_3-groundwater-type (1) and the Ca-SO_4-groundwater-type of the karst springs (3). The concentration ranges of elements like CO_2, HCO_3, K (June samples), Mg, Ca, SO_4, Li, SiO_2, F, B, Li, Cr, Ni, Sb, Sr, Ba (June and October samples) and also the isotopes ^{2}H and ^{18}O confirm this.

Mg concentrations (23-60 mg/L) are slightly increased compared to average groundwaters with 0-50 mg/L (App.No.36) as well as Ca concentrations (210-394 mg/L), that exceed the 60-130 mg/L expected for limestone aquifers.

Higher concentrations than in the cluster groups 1 or 3 occur for the elements Na, Cl, NO_3, Al, Cu, Zn, Cd, As (ICP), Se and Sc, suggesting an additional natural or man made influence. For NO_3 e.g. the concentrations are, comparable to the ones from group (1), locally increased. Amazingly the NO_3 concentrations of P12, next to a cattle ranch with a manure heap, are negligibly low. Na and Cl concentrations are increased in the well samples of Chilera, Dona Matilde, El Peloteado and El Encinito I. Zinc concentrations are especially increased in the well Chilera with 42 µg/L compared to a worldwide average of less than 10 µg/L.

As it was already mentioned in chapter 5.2.1.2.1 B, Co, Cu, F, Li, Ni and Sr concentration are higher than in group (1) but lower than in (3) or (4). Sb concentrations are equally increased in the groups (2), (3) and (4) compared to group (1) and to a worldwide average (0.1 µg/L). The elements As-Se-Tl-U show locally higher concentrations in the wells Chilera, El Peloteado and Dona Matilde.

The most important super-saturated phases are $Ba_3(AsO)_4)_2$ (SI = 5.37) and $BaSO_4$ showing the highest super-saturation of all groups with a saturation index of 0.37.

Ba in solution mainly occurs as Ba^{2+} (61%) like in group (1), but the share of the uncharged complex $BaSO_4$ is higher (38%) than in group (1) (Fig.104).

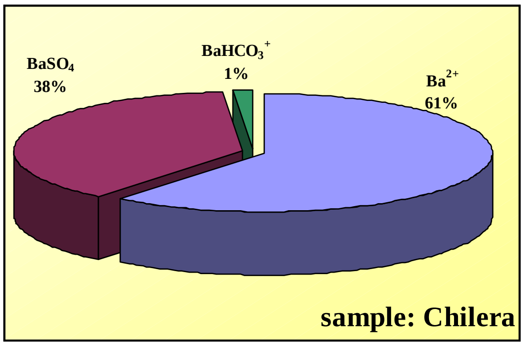


Fig. 104 Main species distribution for Ba - representative example Chilera

5.2.1.2.2 Restrictions and limitations for water use

In June and October 1999 the following parameters exceeded drinking water standards in the sampled drinking water wells (Tab.18)

Tab. 18 Parameters exceeding drinking water standards in the sampled drinking water wells in June and October 1999 (standards from the German TrinkwV 1990 and the Norma Mexicana 1994)

	P12	Chilera	TrinkwV / Norma Mexicana
June 1999			
temperature [°C]	28.9	---	25 / no
Mg [mg/L]	62.11	---	50 / no
SO_4[mg/L]	779.1	514.13	240 / 400
Al [µg/L]	856.01	---	200 / 200
Mn [µg/L]	1378.29	---	50 / 150
Fe [µg/L]	668.48	219.98	200 / 300
October 1999			
temperature [°C]	28.9	---	25 / no
Mg [mg/L]	56.69	---	50 / no
SO_4[mg/L]	745	393	240 / 400

Compared to the drinking water wells of group (1) these two water samples (P12, Chilera) show generally higher mineralization, presenting a problem especially with the high sulfate contents. Additionally for P12 the Al content is exceeding drinking water standards by 400%, Mn by 2756% (920% by Mexican standards). Increased iron contents exceed the standards as in the wells P16 and PSD (group (1)).

The screening for pesticides showed that both wells exceed maximum concentration levels (MCL) set by the EPA or the WHO for heptachlor, aldrin, dieldrin, endrin and the sum of DDT, DDE and DDD. The sum of all pesticides is significantly higher than the 500 ng/L permitted by the strict German TrinkwV (1990) for drinking water.

Tab. 19 Pesticides exceeding EPA drinking water standards in the sampled drinking water wells in July 1999 (concentrations in ng/L)

pesticides	**P12**	**Chilera**	drinking water limitations
Heptachlor (GC-ECD)	215	178	30 WHO
Aldrin (GC-ECD)	279	176	30 WHO
Aldrin (GC-MS)	n.d.	597	30 WHO
Dieldrin (GC-ECD)	362	243	30 WHO
Endrin (GC-ECD)	157	279	200 EPA
Σ DDT, DDD (GC-ECD)	2878	1957	2000 WHO
Σ DDT, DDD (GC-MS)	n.d.	2792	2000 WHO
sum of determined organo-chlorinated pesticides (GC-ECD)	4222	3757	500 (TrinkwV 1990)

For irrigation caution has to be used as all the samples are classified as C3-S1 (Fig.102), presenting high risk of salinity especially on soils that are hard to drain like the fine sand or clay layers in the southwestern part of the basin. Like within group (1) the determined Li concentrations vary considerably from the June sampling (0.01-0.06 mg/L) to the October sampling (1.4-2.12 mg/L) and may present a risk for sensitive plants like citrus fruits. Concerning boron, which is toxic for citrus fruits in concentrations of more than 1 mg/L, there is no risk in using the sampled well water as irrigation water (detected concentrations 0.02-0.04 mg/L).

5.2.1.3. Group (3) - karst springs

members (4): Media Luna, Anteojitos, Ojo de Agua de Solano, Charco Azul

water used as irrigation water and for swimming, washing, etc.

5.2.1.3.1 Characterization --- **Ca-SO_4 springs with high temperature and total mineralization**

The members of cluster group (3), all karst springs, show the most uniform internal chemistry with high temperatures (29.6°C (June) / 28.1°C (October)), high mineralization / conductivity (1775 µS/cm (June) / 1710 µS/cm (October)) and a predominancy of SO_4 and Ca (SO_4 > Ca).

Calcite is significantly super-saturated in all samples (∅ SI_{CaCO3} = 0.38) as well as aragonite (∅ SI_{CaCO3} = 0.24), while gyspum and anhydrite are undersaturated (∅ $SI_{CaSO4*2H2O}$ = -0.37, ∅ SI_{CaSO4} = -0.57) (App.No.32).

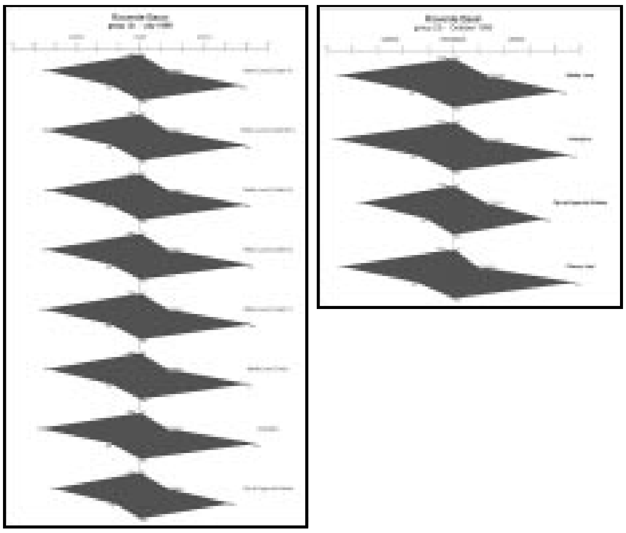


Fig. 105 Stiff diagrams group (3) (left: samples from June, right: samples from October)

Additionally to Ca and SO_4 Mg and HCO_3 are of some importance. Only small amounts of Na, Cl and K were measured. Very low nitrate concentrations in contrast to group (1) and (2) are remarkable.

Concentrations of elements determined with ICP-MS are increased compared to the El Refugio samples but still low compared to the Pastora samples. Arsenic and selenium concentrations are low with 5-6 respectively 3 µg/L.

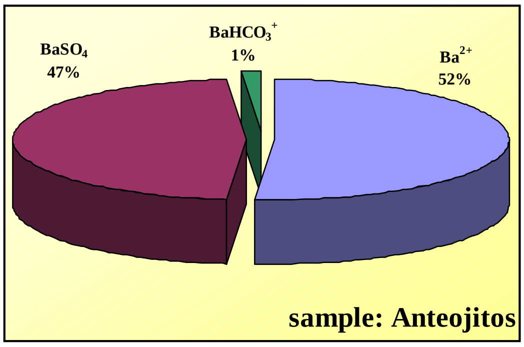


Fig. 106 Main species distribution for Ba - representative example Anteojitos

For $Ba_3(AsO_4)_2$ the super-saturation is lower than in group (1) (SI = 4.3). Inspite of higher SO_4 concentrations $BaSO_4$ is only slightly super-saturated (SI = 0.10) compared to group (2), maybe due to about 50% lower Ba concentrations.

In solution the share of Ba^{2+} (52%) and the uncharged complex $BaSO_4$ (47%) is almost equal (Fig.106), but the total Ba concentrations are too low to present problems for the water quality.

5.2.1.3.2 Restrictions and limitations for water use

As it was already mentioned before Media Luna is the most important irrigation water base, though the water presents a high risk of salinity, classified as C3-S1 in Fig.102 like all the other karst springs. Irrigation therefore should only be applied on permeable soils that show sufficient drainage. Contrary to the other 3 groups the risk from lithium (about 0.04 mg/L in June) and boron (about 0.17-0.35 mg/L in June) is low.

5.2.1.4. Group (4) - Pastora wells

members (9): La Cabana, Pastora, Chamizal, San Isidro, Santo Domingo, Vergel I, Vergel II, Rancho #13, La Gloria water used as irrigation water

5.2.1.4.1 Characterization--- **Ca-Mg-SO_4 groundwater with very high total mineralization**

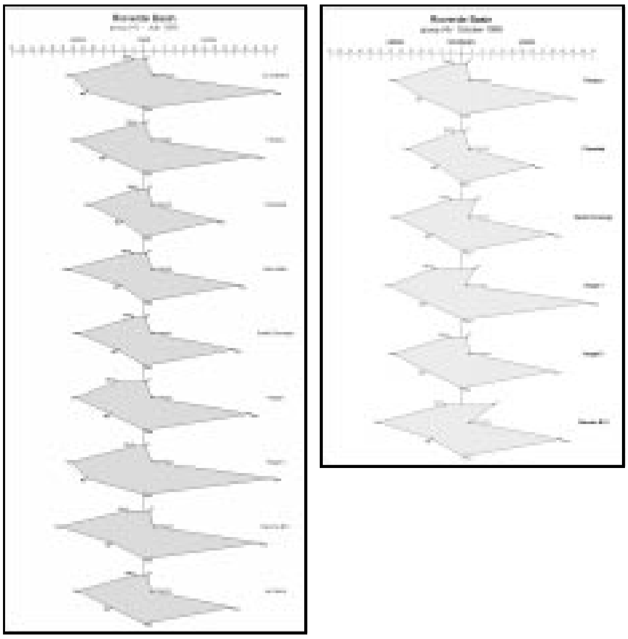


Fig. 107 Stiff diagrams group (4) (left: samples from June, right: samples from October)

The wells of cluster group (4) have the lowest temperature of all sampled wells with 25.2°C (June) / 24.3°C (October) and the highest mineralization / conductivity (3130 µS/cm (June) / 3127 µS/cm (October)).

Besides SO_4 and Ca (SO_4>>Ca) Mg predominates in the chemical analysis (except for San Isidro June 1999) with 106 to 275 mg/L compared to an average worldwide natural range of 0-50 mg/L (App.No.36). Compared to group (3) the dolomite supersaturation though is low with only 0.18 (App.No.32).

The high Ca concentrations of 430-666 mg/L lead to a supersaturation of calcite (∅SI_{CaCO3} = 0.19), though not as high as in group (3). The discrepancy can only be explained by gypsum contact where $CaSO_4$ is the limiting phase for Ca precipitation. App.No.32 shows that the groundwater samples from this group are the only ones that are at or close to equilibrium with gypsum ($SI_{CaSO4*2H2O}$ = -0.19 to 0, ∅ –0.06). Anhydrite is still under-saturated (∅ SI_{CaSO4} = -0.28).

Compared to group (1) aquatic SO_4-complexes predominate over HCO_3-complexes. The share of free ions is the lowest of all groups due to the high total mineralization (Fig.108, Fig.99).

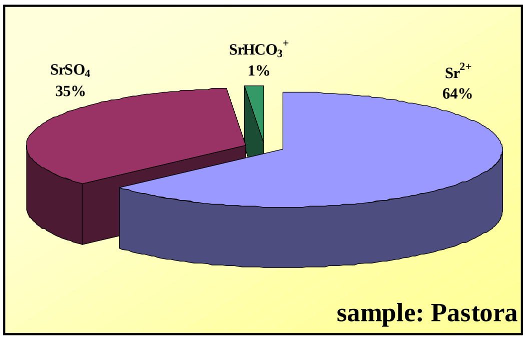
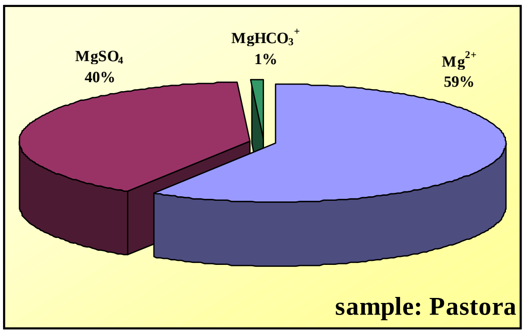
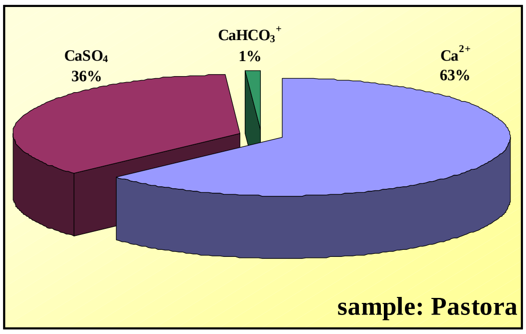


Fig. 108 Main species distribution for Sr, Mg and Ca - representative example Pastora





Na concentrations (51-251 mg/L) are increased compared to other groups (lowest concentration 1.4 times higher than the highest of other groups) and lead to a comparatively low Ca/Na ratio. The distribution of high Na concentrations varies within the group and the two sampling times, especially high values were found for Vergel I and Rancho #13. K concentrations are also higher than in the other groups with an average of 12.5 mg/L, the lowest value is 2.5 times higher than the highest of all other groups.

HCO_3 only plays a minor role compared to the other groups. Cl, normally <30 mg/L in groundwater, showed 12-80 mg/L (average 35 mg/L) in June and significantly higher concentrations during the second sampling in October with 38-450 mg/L (average 168 mg/L; Vergel I: 190 mg/L, Santo Domingo: 200 mg/L, Rancho #13: 450 mg/L).

NO_3 concentrations vary within the group and the two sampling times, in June the values from Vergel I, La Gloria, San Isidro and Rancho #13 were slightly increased, in October the concentrations were generally higher with peaks in the Vergel I, Santo Domingo and Rancho #13 samples. The wells of group (4) are also the only ones that show significant DOC (dissolved organic carbon) contents at all with a maximum of 6.69 mgC_{org}/L for the Vergel I sample and smaller ones for Rancho #13, Vergel II and Santo Domingo.

Combined with the highest total mineralization this group also shows the highest concentrations for B, Co, Cu, F, Li, Ni and Sr. Average fluorine concentrations of 1.92 mg/L (June) respectively 1.85 mg/L (October) with even the lowest value being 1.2 times higher than the highest from any other group lead to a lower under-saturation of the mineral phase fluorite than in the other groups (∅ SI_{CaF2} = -0.17 compared to group (1) ∅ SI_{CaF2} = -1.68, group (2) ∅ SI_{CaF2} = -0.85 and group (3) ∅ SI_{CaF2} = -0.44).

For B the lowest value is even 4 times higher than the highest from other groups and concentrations of 166-350 µg/L exceed by far the worldwide average of a few to 65 ug/L.

Especially interesting are the increased Ni concentrations since about 3/4 of the Ni in solution is represented as uncharged, very mobile $NiCO_3$ complex (Fig.109).

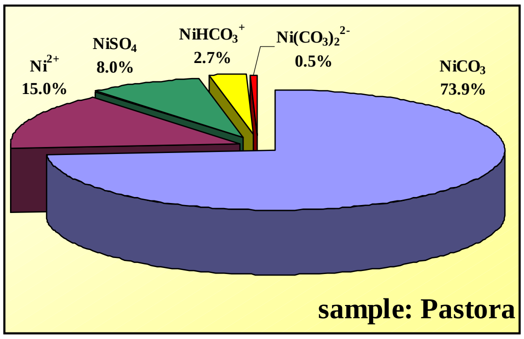


Fig. 109 Main species distribution for Ni - representative example Pastora

As-Sb-Se-Tl-U are increased in the samples Chamizal, Rancho #13 and Santo Domingo. Combined with the higher arsenic concentrations Ba concentrations and the super-saturation of $Ba_3(AsO_4)_2$ (SI = 4.34) are lower. The ratio of the Ba^{2+} ion and the $BaSO_4$ complex in solution is comparable to the ones from group (2) and (3) (57% : 42%). Locally increased values for Cr were determined for Rancho #13, Santo Domingo and Pastora.

5.2.1.4.2 Restrictions and limitations for water use

For irrigation use the water is classified as C4-S1 (Fig.102) with a very high risk of salinity. Group (4) is the only group with an increased SAR (especially Vergel I) but still plots in the S1 field with low risk of sodium. Due to the very high risk of salinity irrigation should only be applied on soils that show good permeability like the porous tuffs around Pastora. A decrease in the yield of plants that are very sensitive to salinity may occur (chapter 5.2.1.1.2). Especially for citrus fruits the high concentrations of Li in the irrigation water (0.08-0.14 mg/L in the July samples; 3.2-5.9 mg/L in the October samples) is dangerous. B concentrations of 0.8 mg/L, 1.5 mg/L and 1.6 mg/L determined in the wells Pastora, Rancho #13 and Vergel I in October 1999 may already be toxic for citrus fruits.

5.2.2. Simulation of the origin of the 4 different water types

5.2.2.1. Stabile isotopes

Fig.110 shows the diagram of the stable isotopes Oxygen (^{18}O) and Deuterium (^{2}H) for the sampled wells in the Rioverde basin. How this information can be used for hydrogeological interpretation of the groundwater recharge area and the effect of evaporation on the groundwater is explained in chapter 3.3.3.2.2.

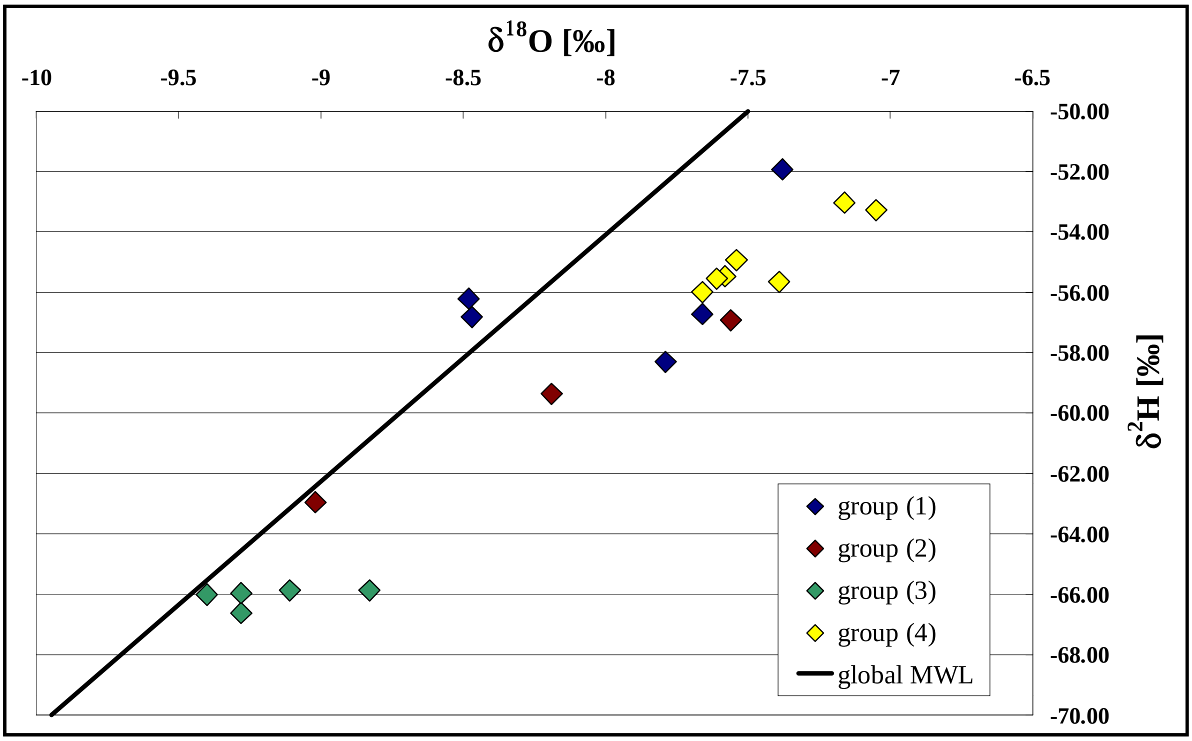


Fig. 110 $\delta\ ^{18}O$ and $\delta\ ^{2}H$ diagram for the 4 cluster groups in the Rioverde basin

With mean $\delta^{18}O$ values of -9.18 ‰ and $\delta^{2}H$ values of -66.06 ‰ (green rhombus in Fig.110), group (3) shows the most depleted isotopic composition of all sampled wells. According to Fig.40 mean Mexican $\delta^{18}O$ concentrations at sea level are about -5 ‰. This means with -9 ‰ and an assumed decrease of $\delta^{18}O$ by 2 ‰ for 1000 m altitude the groundwater recharge area of these karst springs is supposed to be located at about 2000 masl in the western Sierra which is in accordance with the actual altitude. Remarkable is the plotting of all the samples of group (3) close to the global MWL, indicating only minor evaporation effects after infiltration of meteoric water.

Group (4) has the highest $\delta^{18}O$ (-7.43 ‰) and $\delta^{2}H$ (-54.84 ‰) values (yellow rhombus in Fig.110). Since the ^{18}O range is about -2 ‰ lower than the one from the karst springs the recharge area should also be approximately 1000 m lower, at about 1000-1250 masl, in the basin and at some nearby smaller hills. All samples cluster close together in the $\delta^{18}O$-$\delta^{2}H$-diagram, except for Santo Domingo and Rancho #13 that plot a little bit further outside. The samples show the highest d_{exc} values and plot furthest to the right from the MWL; this indicates stronger evaporation effects.

Group (1) shows mean concentrations of -7.96 ‰ $\delta^{18}O$ and -55.99 ‰ $\delta^{2}H$ (blue rhombus in Fig.110), but the individual distribution is quite different. P16 and P17 plot left of the global MWL, PSD has the highest Deuterium concentration of all samples. In average the isotopic composition is between the enriched Pastora samples and the depleted karst samples characterizing groundwater recharge both from inside the basin like Pastora and from the western Sierra like for the karst springs. For P3, P9 and PSD the evaporation effect is almost as important as for the Pastora samples in contrast to the karst springs.

The 3 members of the isotopic group (2) show some differences in their isotopic composition, sample Chilera almost represents average composition ($\delta^{18}O$ -8.26 ‰, $\delta^{2}H$ -59.76 ‰) (red rhombus in Fig.110). Like with chemical composition this group presents influences both of group (1) and group (3). The isotopic composition of P12 comes closer to the one of the karst springs, the one from El Peloteado is alike with the one from group (1). Evaporation effect increases with increasing isotopic enrichment from P12 to El Peloteado.

5.2.2.2. SiO_2-Geothermometer

As it was described in chapter 3.3.3.2.3 SiO_2 was used as geothermometer to determine the approximate circulation depth of the groundwater types.

For group (1) the SiO_2 concentrations showed two maxima, one at about 25-35 mg/L the other at about 45-55 mg/L (blue circles and rhombus in Fig.111). In the samples with the higher SiO_2 concentrations (P9, P17, PSD, PSM, Huerta los Pinos, El Peloteado) the SiO_2 modification in equilibrium was the low temperature modification chalcedony compared to the high-temperature modification quartz in the samples with low SiO_2 concentrations. Due to different calculation algorithms (chapter 3.3.3.2.3) the calculated SiO_2 formation temperatures are more or less equal at about 70-80°C. Considering an average annual temperature of 21°C in the basin that has to be subtracted from this calculated temperature the SiO_2 formation temperature may have been about 50-60 °C. Assuming that the geothermal gradient in this area is increased due to the Tertiary volcanism activity e.g. by 5 °C / 100 m the corresponding depth would be 1000 - 1200 m.

Similarly for group (2) with calculated temperatures of 65-80°C the resulting depth would be 900 - 1200 m depth. The SiO_2 temperatures calculated for the karst springs of group (3) (65°C) result in a lower circulation depth (about 850-900 m). However the saturation indices (App.No.32) show that group (3) is the only group in which all SiO_2 modifications show slight undersaturation indicating that no equilibrium was reached at all and the application of the SiO_2 geothermometer is not appropriate.

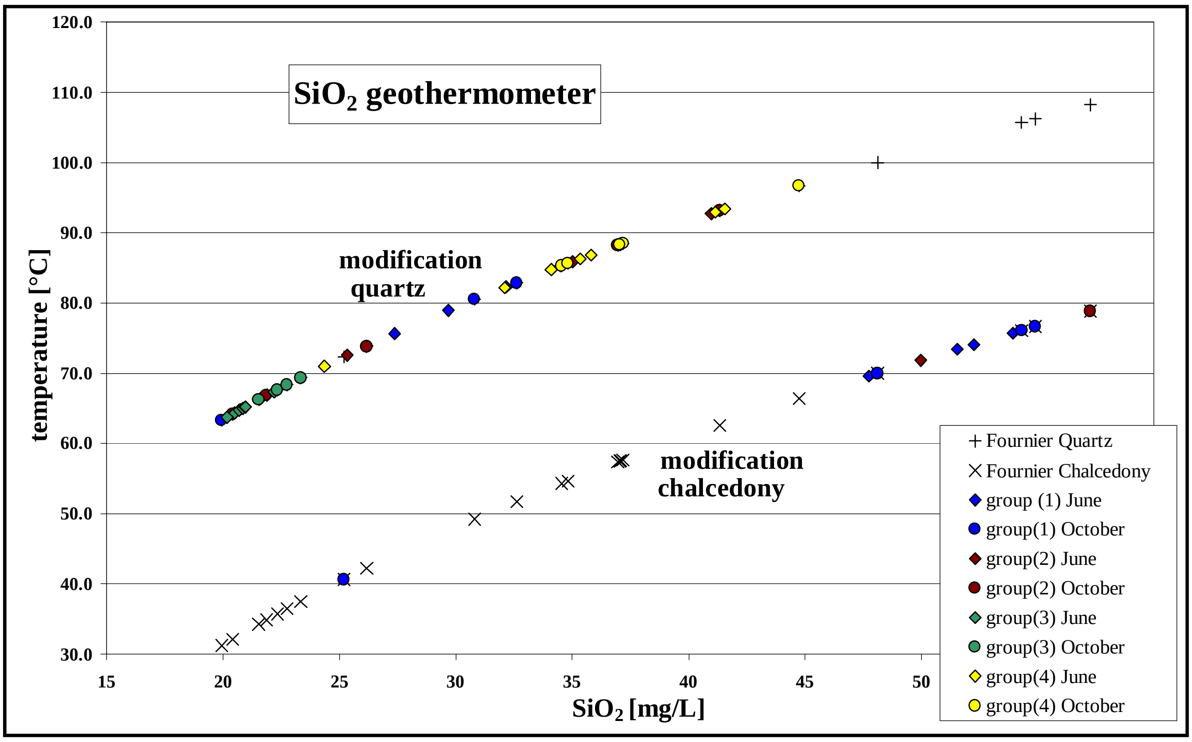


Fig. 111 SiO_2 geothermometer for the 4 cluster groups in the Rioverde basin (circle: sampling from June/ July 1999; rhombus = sampling from October 1999)

Group (4) shows the highest calculated temperatures with 80-95°. Considering the geological surroundings the recent Quarternary volcanism should lead to an increased geothermal gradient compared to El Refugio area, assuming 1 °C more (6°C / 100m) the depth would be 1000-1200m like in the other 3 groups.

It is not easy to answer the question *where* the equilibrium with SiO_2 may have settled. One possibility could be further away in the Sierra at altitudes of 1250-1500 masl with more than 1000 m overlying rocks where the water circulating in the Cretaceous karst systems gets into contact with rhyolith. At least for Pastora with a presumed recharge area at 1000-1250 masl this can not work out. Another possibility would be that the equilibrium is just reached in about 1000 m depth in the basin, maybe in the fault zone, that is supposed to border the tectonic graben structure on the western side. Assuming that this fault zone is filled with mylonites and slows down the water circulating rapidly in the karst systems it would control most of the chemical equilibrium reactions.

5.2.2.3. Hydrogeochemical model

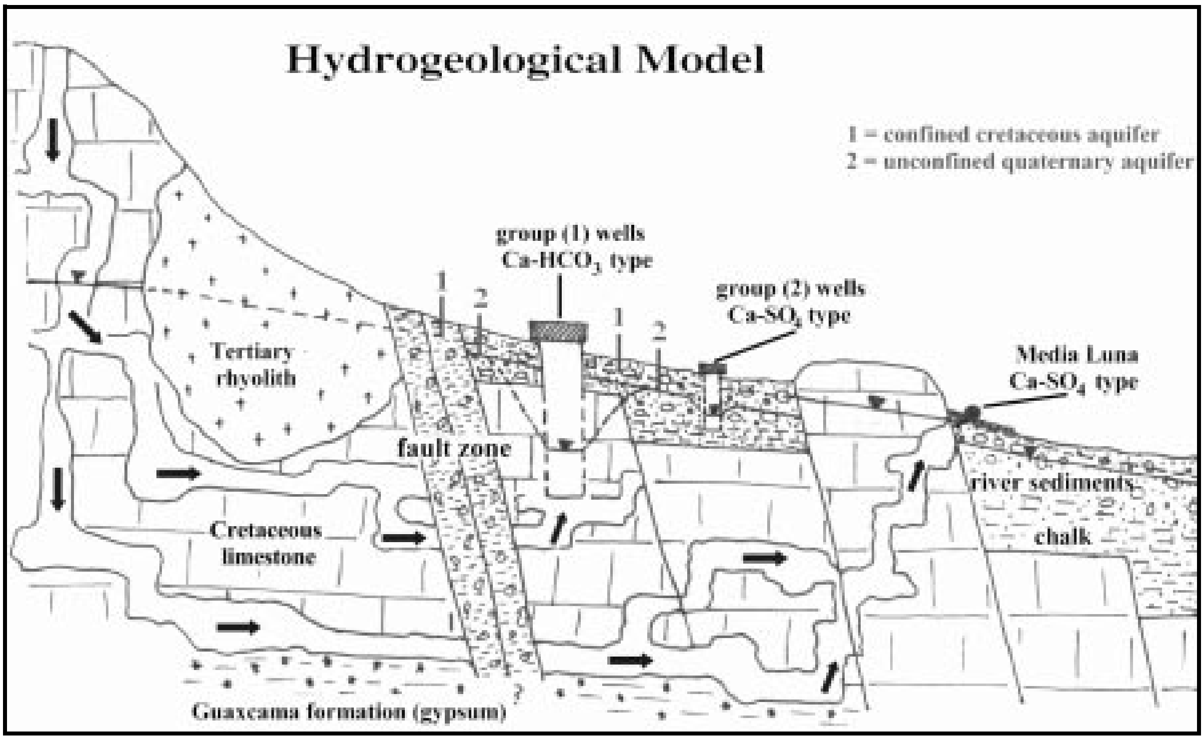


Fig. 112 Hydrogeological model visualizing the relationship between the two main aquifers in the Rioverde basin (Cretaceous, Quarternary) and the chemistry of the cluster groups (1), (2) and (3) (neither vertically nor horizontally to scale) (see also Fig.92)

Except for P3 and P9 all the wells of group (1) penetrate the Quarternary basin fill (well depth 130-200 m, basin depth 0-100 m) [for El Encinito II and Huerta los Pinos no information about the well depths were available]. They pump water from the Cretaceous aquifer that is confined (chapter 5.1.1) which results in differences from 5 to 50 m between static and dynamic level. This effect is probably also responsible for higher differences in the chemical analysis within the group and between the two sampling series compared to the other 3 groups. The main chemical composition Ca-HCO_3 and as well slightly increased uranium concentrations derive from contact of the groundwater with the Cretaceous limestone (App.No.17).

Additionally due to their permanent high pumping rate the drinking water wells create deep depression cones and as consequence leakage of groundwater from the overlying Quarternary aquifer. According to the results from the stabile isotopes the share of shallow water should be almost 50%. The aquatic chemistry reflects this influence, increased concentrations of elements like Ba, Nd and Pb probably result from the contact of the groundwater in the Quarternary aquifers with clay layers (App.No.17). Man made contaminations like NO_3 and pesticides also proves an infiltration of water from the surface.

The wells of group (2) are generally shallower, pumping from an unconfined Quarternary aquifer. Even the drinking water well P12 does not penetrate the Quarternary sediments (well depth 150 m, basin depth 250 m). From the chemical results it is not possible to distinct between different Quarternary aquifers though according to geology (interbedding of gravel - sand - silt - clay) their existence is assumed.

The main difference to group (1) are the higher sulfate concentrations. They are supposed to result from the location closer to the center of the basin where the whole sediment is thicker and lacustrine sediments predominate fluvial sediments. Slightly higher concentrations of elements like Na, Cl, Al, As and Se show the chemical influence of these evaporites. Due to the high potential level of the Cretaceous confined aquifer in some parts there may also be a chemical influence of groundwater infiltrating from the bottom through leakage.

The karst spring Media Luna owes its existence to the tectonic ridge forming the hill southwest of El Jabali. Water recharged about 60 km to the west at altitudes of about 2500 masl flows in the karst system and is upwelling at the hill´s steeper eastern side where the potential level of the confined Cretaceous aquifer is just slightly above the surface. The idea that Media Luna is fed from water from different horizons respectively aquifers was disproved with the very similar chemistry of all 6 craters. The high temperatures conserved in this and the other karst springs from group (3) indicate a rapid upwelling of the groundwater conserving some of the geothermal heat. This rapid movement is also proved by the fact that in all samples no SiO_2 modification reached equilibrium.

The high sulfate concentrations in all karst water samples can only be explained by contact to the Lower Cretaceous gypsum formation (Guaxcama) deposited below the El Doctor limestone. Compared to group (1) a deeper circulation in the karst system is assumed. Contact with gypsum containing Quarternary sediments like group (2) is excluded as it would contradict the rapid upwelling theory.

Very interesting is the fact, that the rio verde spring Ojo de Agua de Solano also belongs to the system of karst springs and is no Quarternary spring. Topographically it forms a line with Media Luna on which also the so called "fault well" is located. This "fault well", just next to the highway Rioverde-San Luis Potosi, is build over a natural fracture zone. Unfortunately no sample could be taken from this well as it was not flowing during the entire time of field investigation.

The Pastora wells (group (4)) show a complete different origin. They also pump from an unconfined Quarternary aquifer, except for the well Rancho #13 and maybe Santo Domingo. But in contrast to El Refugio area there are probably no distinctive different Quarternary aquifers but lateral changes from few fine-sand parts of better permeability to large areas of chalk with lower permeability. According to the stabile isotopes the recharge area is much closer on the nearby hills to the northwest, at most a few hundred meters higher than the basin´s floor. The amount of groundwater recharge is lower, evaporation plays a major role.

The chemistry is both influenced by the evaporites (Ca, SO_4, Na, Cl) and the Quarternary volcanism (Ni, Cr, Cu, Zn, Sr, Ba from the tuffs and basalts, App.No.17). It is interesting that the two wells that probably pump a mixture of Cretaceous and Quarternary groundwater (Rancho #13, Santo Domingo) have the highest As concentrations. Compared with group (1) the arsenic source is probably the same (El Doctor limestone), but the higher Ba concentrations from the clay in El Refugio seem to control As concentrations quite effective.

5.2.2.4. Inverse modeling with PhreeqC

The theoretical background for inverse modeling with PhreeqC is explained in chapter 3.3.3.2.1, the corresponding input files for each modeling can be seen in App.No.34. Tab.20 shows that it is generally possible to reconstruct the supposed hydrogeochemical model with invers modeling even though some decisive elements, e.g. Pb and Ba for group (1) or As, Ni, Cu, Cr for group (4) were not considered since on the one hand the determination of the trace elements in the few rock samples was not sufficient and on the other hand for some of the elements not only mineral phases but also solid solutions play an important role for the behaviour in aquatic environments.

Especially significant is the amount of gypsum that has to be dissolved: 40 mmol/L for Pastora compared to only 0.35 mmol/L for P9. Already mentioned in chapter 5.2.1.1.1 the under-saturation of group (1) with regard to calcite causes the need of further calcite solution compared to the rain water (1.45 mmol/L) while for Media Luna and Pastora 8.56 mmol/L respectively 30.4 mmol/L calcite have to precipitate. The fact that it is possible to model the Chilera sample without calcite or dolomite proves that the influence of Cretaceous groundwater is low for this group.

The fact that the reacting minerals are more or less the same for all samples is owed to little differences in the mineral composition of e.g. Quarternary chalk and Cretaceous limestone considering only the main ions. For further differentiation it would be necessary to use distinct rare elements. The share of rhyolithic minerals in the Cretaceous karst groundwater of P9 and Media Luna is supposed to come from the fault zone probably filled with a melange of rhyolith and limestone blocs in sandy-clayey matrix.

Tab. 20 Amounts of each mineral in mol/L that have to be dissolved (+) or precipitated (-) in order to obtain the 4 groundwater samples P9, Chilera, Media Luna and Pastora from low mineralized rain water (KX, CaX_2 = kation exchanger, abbreviations = supposed geological formation in which the reaction occured: Qv = Quarternary volcanics, Qs = Quarternary sediments, R = Tertiary rhyoliths, C = Cretaceous El Doctor limestone, LC = lower Cretaceous Guaxcama gypsum formation)

mineral		P 9		Chilera		Media Luna		Pastora	
Gypsum	$CaSO_4{:}2H_2O$	3.51E-04	Qs	1.07E-02	Qs	1.99E-02	LC	4.32E-02	Qs
CO_2(g)	CO_2	8.98E-04	R	3.17E-03	Qs	7.81E-04	R	6.11E-04	Qs,Qv
Calcite	$CaCO_3$	1.45E-03	C	---		-8.56E-03	C	-3.04E-02	Qs
Dolomite	$CaMg(CO_3)_2$	4.44E-04	C	---		5.39E-03	C	1.53E-02	Qs
CaX_2	CaX_2	-7.70E-05		2.34E-04		-4.20E-05		-1.37E-04	
KX	KX	1.54E-04		-4.68E-04		8.40E-05		2.74E-04	
Quartz	SiO_2	-1.14E-04	Qs,R	-1.94E-03	Qs	-7.60E-04	R	-4.71E-03	Qv
Biotite	$KMg_3AlSi_3O_{10}(OH)_2$	---		5.82E-04	Qs	---		---	
Kaolinite	$Al_2Si_2O_5(OH)_4$	-2.54E-04	Qs,R	-6.55E-04	Qs	-2.75E-04	R	-1.33E-03	Qv
Albite	$NaAlSi_3O_8$	5.07E-04	Qs,R	7.27E-04	Qs	5.50E-04	R	2.66E-03	Qv
Halite	NaCl	3.11E-04	Qs	5.43E-04	Qs	1.98E-04	LC	2.89E-04	Qs

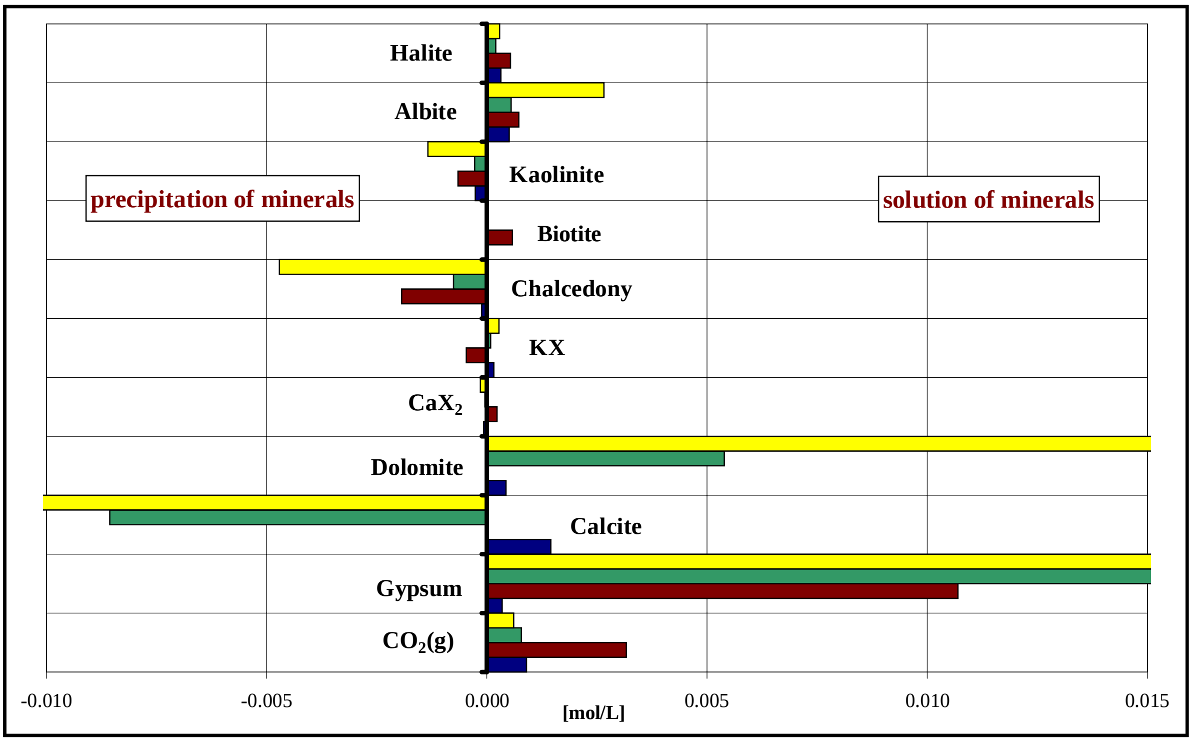


Fig. 113 Graphic presentation of the results from inverse modeling with PhreeqC (x-axis: amounts of each mineral in mol/L that have to be dissolved (+) or precipitated (-) in order to obtain the 4 groundwater samples P9 (blue), Chilera (red), Media Luna (green) and Pastora (yellow) from low mineralized rain water; KX, CaX_2 = kation exchanger; bars cut for Pastora dolomite, calcite and gypsum and Media Luna gypsum; corresponding data see Tab.20)

5.2.3. Arsenic field method

5.2.3.1. Arsenic field results

Since the first own field determinations of arsenic in June 1999 in a small area southwest of the main town Rioverde (El Refugio area) showed significantly lower arsenic concentrations with maximum values of about 10 µg/L, 50 wells spread all over the southern part of the basin were examined for arsenic covering roughly an area of about 40 km north-south and 30 km west-east.

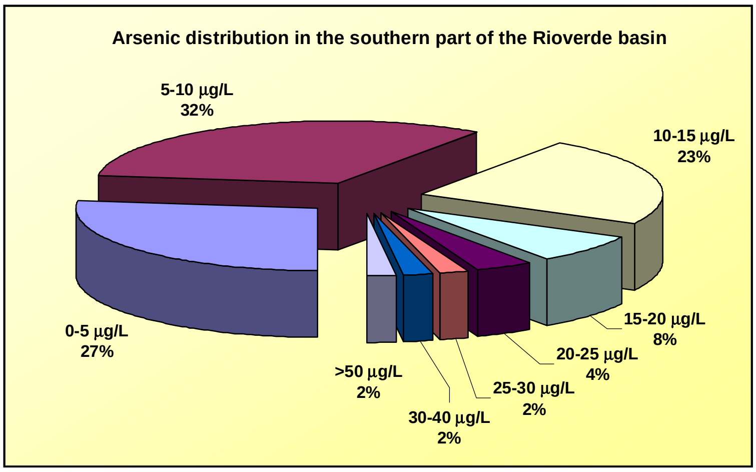


Fig. 114 Distribution of Arsenic concentrations in the southern part of the Rioverde basin according to determinations from June 1999

The maximum values found were about 50 µg/L (Fig.114, Fig.115).

Thus it can be stated definitively that the reported values of several mg/L from HOFMANN (1994) and DE LA PENA GAMEZ (1994) are wrong, perhaps a change of units between mg/L and µg/L.

Even if the determined arsenic concentrations are not as alarmingly high as expected, they are still increased compared to areas without natural arsenic sources (0.5-5 µg/L) and so arsenic was determined in all wells of the two described study areas El Refugio and Pastora as well as in the springs (App.No.35).

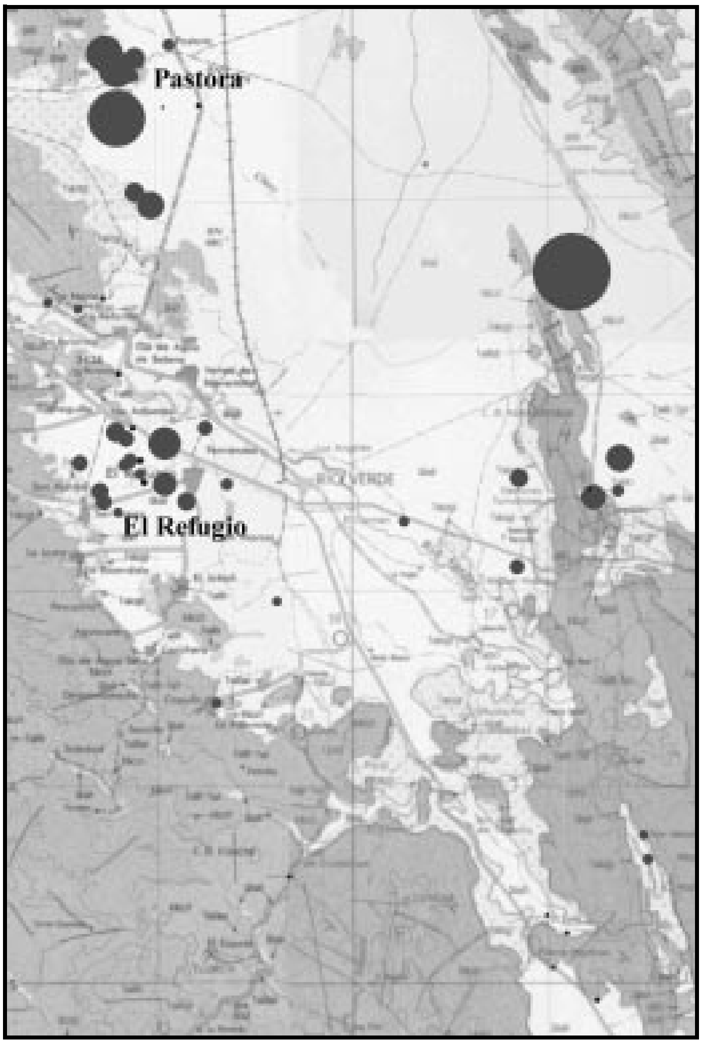


Fig. 115 Southern part of the Rioverde basin with the Arsenic concentrations of the well waters determined in June 1999 (differences in circle seize reflect concentration differences, red = wells with concentrations of >5µg/L)

5.2.3.2. Suggestions for improvement of the method

In chapter 3.3.2.2 the theoretical background of the new arsenic determination method according to VOLKE & MERKEL (1997) was presented. After this pilot project in Mexico suggestions for improvements and evaluations can be made for the equipment´s prototype.

<u>5.2.3.2.1 Field application</u>

Some things are still quite hard to handle in the field without laboratory comfort. Thus it was almost impossible to work without a pair of very exact scales to measure the powder content for the reagent and the potassium iodide solutions. The amount of reagent solution calculated for about 22 measurement (that means 11 wells with double determination for total arsenic and only about 5 wells with speciation) turned out to be too scarce especially with the problem of having no scales in the field. The amount of potassium iodide solution was o.k. Since it is not needed for speciation it lasted for about 40 wells with double determination, but it can be kept normally not more than 1.5, at the most 2 weeks. For tin chloride and copper sulfate solution scales are also needed, but as these solutions are calculated for about 250 total arsenic determination (or 500 speciation determinations for tin chloride) and keep well over several months, they can be mixed in the laboratory before leaving for the field and present no problem.

Anyway for a commercial equipment the use of power pillows is suggested, preferentially with small amounts of reactives in order to avoid unnecessary big amounts of solution. The reduction solution and the reagent solution should be already mixed in small ampoules of 2 ml for speciation and 4 ml for total arsenic determination (reduction solution), respectively 1.7 ml (reagent solution). However at least for the reduction solution this will arise a problem of perishability. Maybe it is also possible to combine several chemical reactives in order to minimize the amount of different reactives, e.g. copper the zinc or press potassium iodide - zinc tabs. One disadvantage of the last mentioned would be that two different kind of tabs will be needed for total arsenic with KI and for speciation without KI probably even complicating the procedure.

The reaction time of 45 minutes is yet quite long, an increase in reaction rate with a minimization of processing time without accuracy loss would be appreciated. Using the pipettes with lead acetate wad a second time turned out to be only advisable for speciation when they were just used for 15 minutes. After an analysis for total arsenic the lead acetate wad pipettes are almost always wet, a second use blocks the arsine stream and the wad shows a yellow-orange color.

A special problem was the cleaning of the cuvets without laboratory equipment. The use of water for cleaning the pyridine cuvets turned out to be fatal since the plastic became dull disturbing the sorbance for the next determination. Even with commercial detergents it was not possible to remove this dulling. The only way is probably keeping the cuvets in pure pyridine for cleaning and storage.

A rack to fix tubes and bottles against eventual fall over would help in windy weather. A professional case for transportation perhaps even with further minimization of the whole equipment, e.g. a smaller photometer, would facilitate field trips.

5.2.3.2.2 Calculation and calibration

Recalculating the formula for speciation determination the formula $c_{As(III)} = (E_{ges.spez} - c_{ges.} * e_{As\,(V)}) / (e_{As\,(III)} - e_{As\,(V)})$ (chapter 3.3.2.2) presented so far in VOLKE & MERKEL (1997) turned out to be a simplification of the original one not taking into consideration the constants from each calibration line´s y-axis intercept. The entire formula is:

$$c_{As(III)} = (E_{ges.spez} + (a_{As(III)} * e_{As\,(III)} + a_{As(V)} * e_{As\,(V)}) - c_{ges.} * e_{As\,(V)} / (e_{As\,(III)} - e_{As\,(V)}) \qquad \text{Eq. (4)}$$
$$c_{As(V)} = c_{ges.} - c_{As(III)} \qquad \text{Eq. (5)}$$

for explication: calibration curve: $c_{As(III)} = a_{As(III)} + b_{As(III)} * E_{As(III)}$

$c_{As(V)} = a_{As(V)} + b_{As(V)} * E_{As(V)}$

$E_{ges.spez} = E_{As(III)} + E_{As(V)}$

$E_{As(III)} = (c_{As(III)} - a_{As(III)}) / b_{As(III)}$

$E_{As(V)} = (c_{As(V)} - a_{As(V)}) / b_{As(V)}$

$E_{As(V)} = (c_{ges.} - c_{As(III)} - a_{As(V)}) / b_{As(V)}$

$E_{ges.spez} = (c_{As(III)} - a_{As(III)}) / b_{As(III)} + (c_{ges.} - c_{As(III)} - a_{As(V)}) / b_{As(V)}$

$c_{As(III)} * (1/b_{As(III)} - 1/b_{As(V)}) = E_{ges.spez} + (a_{As(III)}/b_{As(III)} + a_{As(V)}/b_{As(V)}) - c_{ges.}/b_{As(V)}$

with: a = y-axis intercept

b = calibration line inclination

e = 1/b = extinction coefficient
c = concentration
E = extinction

With the calibration line from VOLKE & MERKEL (1997) the missing constant factor is 4.28 µg/L, therefore Arsenic concentrations calculated with the simplified formula will be too low by -4.28 µg/L.

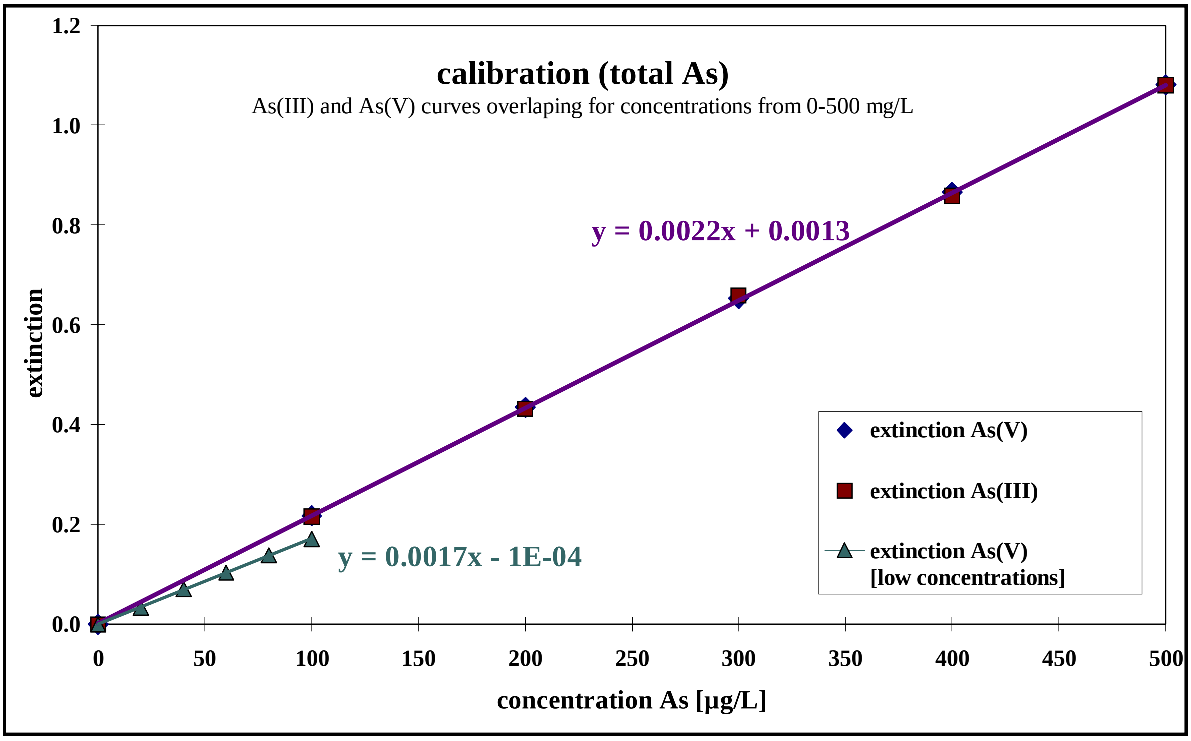


Fig. 116 Calibration line for total arsenic determination with the calibration in the low concentration range (green line)

The calibration line itself calibrated from 0 to 500 µg/L in 100 µg/L steps that was thought to be justified for the reported high concentrations turned out to just a rough estimate for the determination of the unexpected low arsenic concentrations in the study area (<50 µg/L). Therefore a calibration for total arsenic in the lower concentration range (0, 20, 40, 60, 80, 100 µg/L) was done after the field trip in the laboratory of the Freiberg University of Mining and Technology (Fig.116).

This calibration line is linear like the one in the higher concentration range but below it, that means that for the same extinction the concentrations calculated with the new calibration are higher. Comparing the field results calculated from the old and the new calibration with the laboratory results (App.No.35c) there is a better correspondence for the Media Luna and the Pastora samples (except for Vergel I, II and La Gloria) with the new calibration in the low concentration range. Unfortunately the El Refugio field determinations can´t be compared with the lab determinations as they were taken in two different field trips.

Probably it is not advisable to take one "standard calibration" for every sampling, instead an own calibration is prefered for each new determination set being more accurate but also making the method harder to applicate in the field. Maybe it is possible to rely on the linearity of photometric determination according to the Lambert law and just take two concentrations for the calibration and do a linear interpolation between them, but this would have to be proved before with more calibration runs. Anyway the calibration in the field is still hard to handle since it is neither possible to bring scales and different glass retorts outside and do exact dilution nor include prepacked packages of arsenic standards in the determination set, as the calibration concentrations are too low and lost of some power would have severe effects on the calibration solution.

The detection limit (DL) for total arsenic that was reported to be 5 µg/L (chapter 3.3.2.2) was recalculated again according to the following formula:

$$DL = \frac{(\bar{x} + 3 \cdot \sigma)}{\sqrt{n}} \qquad \textit{Eq. (6)}$$

with: x = average extinction of determinations with 0 µg/L As
σ = standard deviation of x
n = number of determinations in the field (here: double determinations, n = 2)

The average extinction from 7 determinations was 0.0026 with a standard deviation of ±0.0013, leading to a detection limit of 0.0045 extinction units (Eq.6) or 2.7 µg/L. This suggests a better detection limit than reported by VOLKE & MERKEL (1997), but with just 7 the number of 0 µg/L-determinations is too low for a final statement. More analysis have to be done in order to verify the detection limit.

5.2.3.3. Comparison of the results from the field method and HGAAS

Additionally to the field method total arsenic was determined by HGAAS (hydride generation atomic absorption spectrometry) in the laboratory (UNAM Mexico). The samples were kept less than 2 weeks in polyethylen bottles in a refrigerator before analyzing them. The effect of changes in total arsenic content can be neglected, van ELTEREN (1991) reports that over a period of 1 month no significant (>2%) sorption of arsenic on the surface of polyethylene containers occurs independent of the storage conditions.

For the unexpected low concentrations (<50µg/L) that were found in the whole study area HGAAS is the better determination method anyway since it is the most accurate one. Moreover the field results suffer from the inaccurate calibration, the resulting concentrations were just converted by the two calibrations done before (calibration in the higher concentration range) and after (calibration in the lower concentration range) the field trip, no calibration was done directly on-site. Consequently the field results differ from the HGAAS results (Tab.21).

But as Tab.21 shows even without on-site calibration the LCC-field results differ just by about ± 6 µg/L from the laboratory results with a maximum negative deviation of -5.6 µg/L and a maximum positive deviation of +2.2 µg/L. The higher negative deviation may indicate that the arsine generation in the field method is yet not optimized and some arsenic escapes the determination maybe dependent on environmental influences like temperature, air pressure, humidity, etc.

In agreement to the idea of keeping the field determination as simple as possible more work has to be done on the calibration to find out how much the values of different calibrations shift and if it is justifiable to use a "standard calibration" with an acceptable accuracy eliminating the difficulty of calibrating in the field.

Tab. 21 Comparison of arsenic concentrations determined in the laboratory (HGAAS) and in the field (converted with two different calibrations: HCC = calibration in the high concentration range, LCC = calibration in the low concentration range) ["+" in the last line indicates an improvement with LCC compared to HCC, "-" a deterioration; concentrations in µg/L]

Pastora	La Cabana	Pastora	Chamizal	SanIsidro	Domingo	Vergel I	Vergel II	Rancho13	LaGloria
laboratory HGAAS	8.59	9.02	26.54	9.82	23.82	7.84	4.15	42.76	4.61
field (HCC)	7.376	5.763	16.366	5.532	19.362	7.837	4.380	29.735	4.61
field (LCC)	9.467	7.409	20.933	7.115	24.755	10.055	5.643	37.985	5.939
difference HCC-lab	-1.21	-3.26	-10.17	-4.29	-4.46	0.00	0.23	-13.02	0.00
difference LCC-lab	0.879	-1.613	-5.605	-2.704	0.932	2.218	1.495	-4.774	1.333
comparison LCC-HCC	+	+	+	+	+	-	-	++	-

springs	Media Luna crater A	Media Luna crater B/C	Media Luna crater D	Media Luna crater E	Media Luna crater F	Media Luna cave
laboratory HGAAS	8.20	8.66	8.57	8.55	8.57	8.25
field (HCC)	3.227	3.458	6.224	5.532	5.763	4.380
field (LCC)	4.175	4.469	7.997	7.115	7.409	5.645
difference HCC-lab	-4.97	-5.20	-2.34	-3.01	-2.81	-3.87
difference LCC-lab	-4.03	-4.19	-0.57	-1.43	-1.16	-2.60
comparison LCC-HCC	+	+	+	+	+	+

Statistic analysis seem to confirm the general reliability of the new field method showing a positive linear correlation between the field and the laboratory results (Fig.117) with a significance level of 5% (95% confidence range). The correlation coefficient between lab and field determination is 0.9733 on a very good significance level of 0.0001 (0.01%). For an ultimate confirmation though the data density is too low.

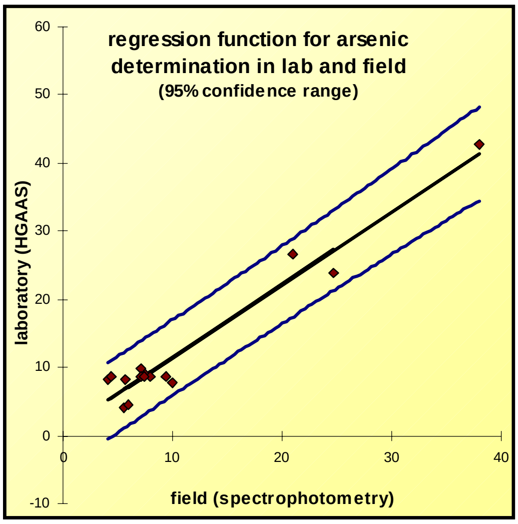


Fig. 117 Regression function for the arsenic determination in the laboratory (HGAAS) and in the field (spectrophotometry)

5.2.3.4. Speciation

For speciation it was not possible to do comparative determinations in the lab as the oxidation of As(III) occurs very rapidly and there are no effective stabilisation methods known yet. To check if the speciation determination is working in principle the E_H and pH values from the samples with arsenic speciation determination were plotted into a predominancy diagram and the resulting predominant species were compared with the amount of As(III) and As(V) determined with the field method (Fig.118, whole pe-pH diagram for arsenic Fig.27).

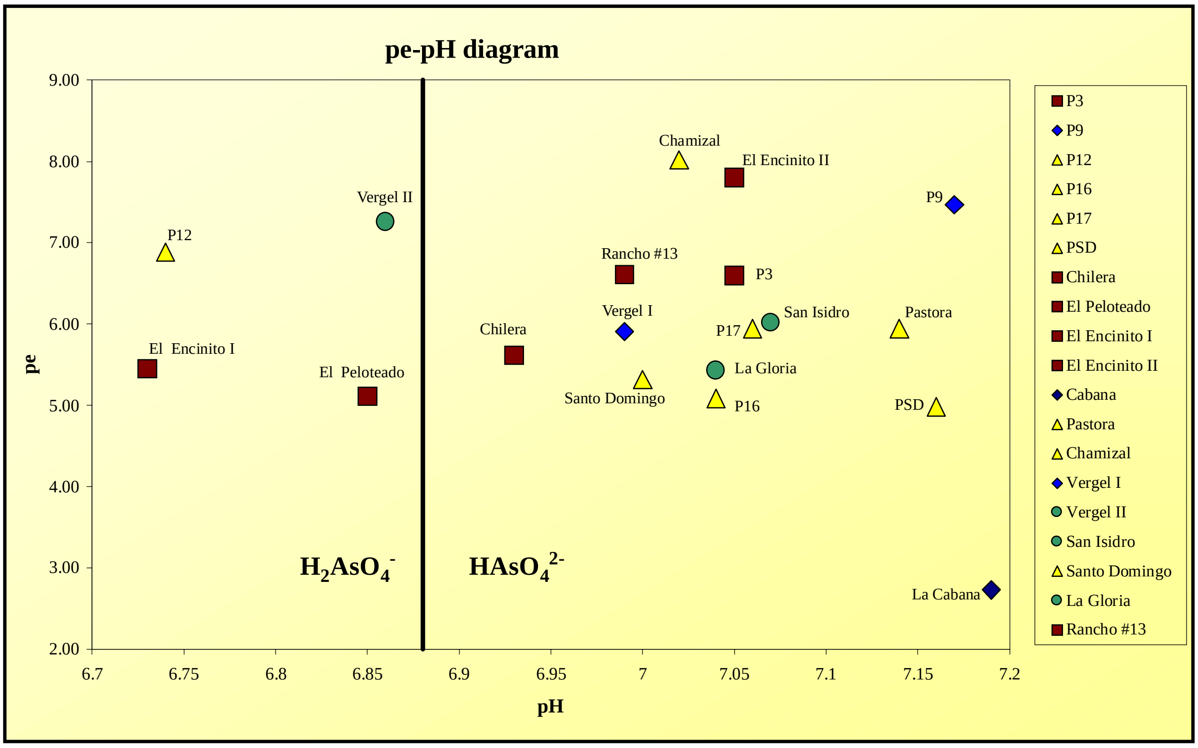


Fig. 118 Detail of an arsenic pe-pH diagram for samples from El Refugio and Pastora plotting in the $H_2As(V)O_4^-$ and the $HAs(V)O_4^{2-}$ predominancy field (colors show the arsenic species determined with the field method: red squares: only As(V); green circle: only As(III); yellow triangles: As(V) > As(III), blue rhombus: As(III) > As(V))

Fig.118 shows that all determined samples either plot in the $H_2AsO_4^-$ or the $HAsO_4^{2-}$ field, both As(V) species. This is inconsistent with the speciation determination calculating significant concentrations of As(III) for San Isidro, Vergel II and La Gloria (green circles, all As as As(III)) as well as as for P9, Cabana and Vergel I (blue rhombus, As(III) exceeding As(V)). Unfortunately the iron determination was not working reliably in the field, otherwise there would have been the possibility to check the speciation distribution with a second redox sensitive couple (Fe(II) / Fe(III)).

Cross-check with the redox sensitive couple of nitrogen ($N(III)O_2$ / $N(V)O_3$) revealed that indeed for the samples San Isidro, La Cabana, Vergel I and P9 (with high As(III) concentrations) the reduced species NO_2 is increased compared to e.g. Chilera, El Peloteado or PSD (with low As(III) concentrations), but on the other hand comparing Rancho #13 ("only As(V) group") and Vergel II ("only As(III) group") both have identical NO_2 concentrations and similar E_H values and it´s the same with P3 and P9. Moreover the ratio of As(V) to As(III) within groups is also insiginificant, e.g. in the sample Santo Domingo almost all As is determined as As(V) (24.1 of 24.8 µg/L) whereas in the sample Chamizal it´s only 3/4 (15.8 of 20.9 µg/L). While the Chamizal point therefore should plot closer to the As(III) field in the pe-pH diagram according to the field determination it actually plots significantly higher than the Santo Domingo point according to the values measured for pH and pe.

Comparison of the results obtained from speciation field determination with the As species distribution calculated with PhreeqC2 (App.No.7) from the ICP-MS results for As also shows bad correlation. Predominant species in all calculations is As(V) (about 10^{-7} to 10^{-8} mol/L). As(III) is almost negligible with 10^{-14} to 10^{-24} mol/L (App.No.35c).

Redox potentials that are used both for the pe-pH diagram cross-check and for the geochemical modelling with PhreeqC2 are certainly difficult to measure but since much time was put on getting reliable pe values significant errors can be excluded. On the other hand it is not yet proved if speciation also works reliably in the low concentration range at issue (max. 38 µg/L). Moreover the transformation of extinctions to concentrations was done with the old calibration from 0 to 500 µg/L in 100 µg/L steps (chapter 3.3.2.2) since there was not enough time to work on a calibration in the lower concentration range from 0 to 100 µg/l in 20 µg/L steps like with total arsenic. As it was shown for total arsenic more detailed calibration can significantly improve the results.

From the experiences made with this first field check arsenic speciation is not working properly within concentrations below about 40 µg/L. For further improvement of the method the speciation determination limit will have to be recalculated and proved with more measurements. A calibration in the lower concentration range will be necessary as well as the check if it is justifiable to use a "standard calibration" with an acceptable accuracy eliminating the difficulty of calibrating in the field like with total arsenic.

5.2.3.5. Evaluation of the method

As it was shown above several things still have to be improved or further simplified in order to use the presented arsenic determination method as a real field method especially for arsenic speciation. But for total arsenic the above mentioned first comparisons between the very accurate HGAAS determination in the laboratory and this relative simple field method showed deviations of about ±6 µg/L, which would be absolutely sufficient especially with the advantage of eliminating any alteration effect due to storage. Though more comparative measurements are needed to get reliable proofs.

Fig.119 and Fig.120 show how much arsenic concentrations can vary with the pumping duration (up to 30 µg/L) and naturally over a certain time period (up to 140 µg/L). It may be possible to eliminate the concentration effect due to insufficient pumping duration, but according to Fig.119 this can already last 1 day.

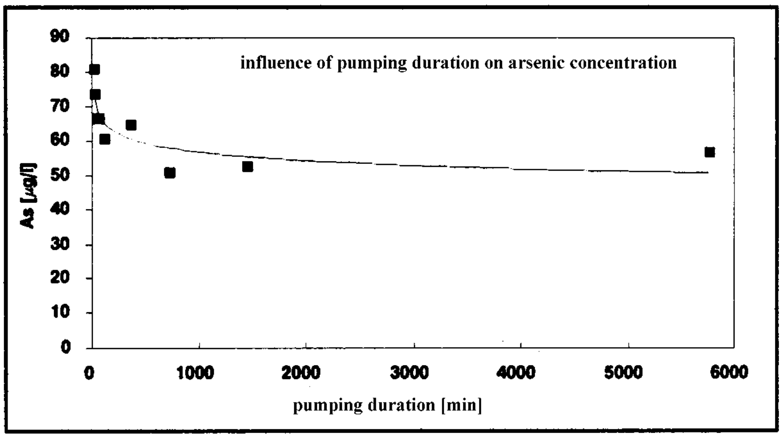
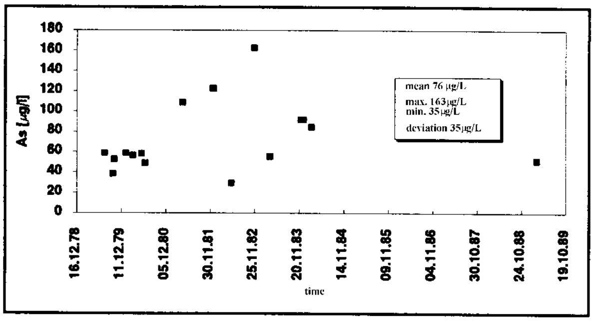
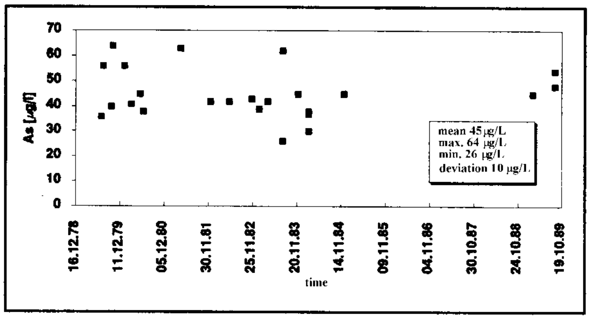


Fig. 119 Influence of pumping duration on the arsenic concentration (HEINRICHS 1996)

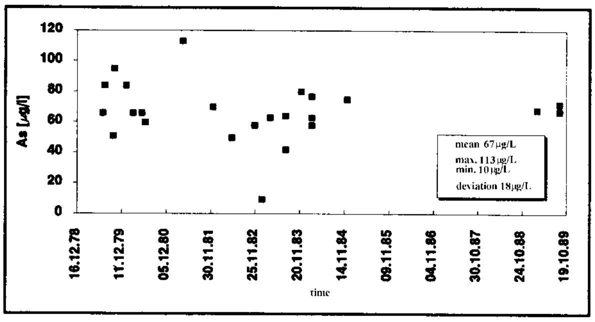
The variation over a certain time period can just be eliminated by repeated determinations over several months. Therefore the possibility of more determinations with a cheap, easy to handle in situ method of acceptable accuracy compared to only one expensive determination with highest accuracy in the laboratory justifies the application of the field method.



well 1: Pfofeld group: As concentrations since 1979



well 3: Pfofeld group: As concentrations since 1979



well 2: Pfofeld group; As concentrations since 1979

Fig. 120 Arsenic concentrations in 3 wells in Germany (Pfofeld) and their hugh annual variations in ten years (HEINRICHS 1996)

6. RECOMMENDATIONS

In the last two chapters several new models and ideas were shown. Due to the limited time for field work (about 3 months), limited funds and occasionally poor reliability of data, some of the presented thesis may be only rough estimations, incomplete or even wrong in parts. To provoke future research to prove or disprove that recommendations for further investigations are presented in the following.

Geology

For closer analysation of the proposed geological model more geophysical sections are required. A systematic network of geophysical sections through the whole basin is recommended in order to check the depth of the Quarternary basin fill. To the west geophysical sections should cross the area in which the graben fault is suspected, trying to find out strike direction, inclination, horizontal extend and depth of the fault. Seismic should be prefered to the geoelectric applied so far, since it covers greater depths. Heatflow measurements could help to locate the fault zone. Besides the geothermal gradient for different areas should be determined, especially in the center of the basin with presumely lower heatflow, the southwestern part of the basin with suspected increased heatflow and the northwestern part, where the greatest heatflow is assumed due to Quaternary volcanism. The determination of the geothermal gradient is important to use the SiO_2 geothermometer correctly and get ideas about different circulation depths.

New drillings should be documented quite carefully <u>on-site</u>. With rotary riggs the problem often occured that clay is washed out with the drilling fluid and later documentation of the sampled rocks can not record this. Rotary drillings should be cored (at least in parts) and the cores should be documented in a central database and stored in wood boxes sorted by depth in a central place preferably in Rioverde itself, accessible to all researchers. Old drillings (wells) where the drilling whole is already cased could be reanalyzed for stratigraphy by γ or γ-γ-log (provided the pump is out).

Exact mapping of the Quarternary by sedimentologists could refine the idea of deposition environments. Probably it is also possible to do further differentation of the Quaternary by satellite images (false color RGBs (red-green-blue)). The false color image with the channels 6-5-7 reveals e.g. the delta of river sediments in the western part of the basin, in contrast to the large areas in the basin covered by chalk. Especially interesting would be trying to find out what the structure in the northeastern part of the satellite image may be, that is significant in all principal component and false color images (blue in 7-5-3, yellow in 1-4-5, red in 6-5-7, wet in brightness-greenness-wetness). The distribution of basalts could also be checked with the satellite images. For confirming the age of the basalts and tuffs only age dating perhaps with the K-Ar-method for basalts is reasonable. The results of the thermoluminiscence dating done for a tuff cone in 1999 will be presented in a later paper.

Hydrogeology

Concerning hydrogeology it would generally help for future interpretation if a database of all the wells existed in a central system accessible to all researchers. Basis for this would be a consistent numbering, signed also on the well itself. Furthermore exact longitude, latitude and especially altitude of the well head would be necessary and information about the well depth, length of the screen, well yield and especially about the geological strata. Single information already exist, but a complete network is missing. New wells should be carefully reported, both the drilling with geological information and especially information of water occurence or rapid upwelling of water in the drilling hole (indicating a confined aquifer), as well as the well construction for depth, length of filter screens, etc. At least for the existing deeper drinking water wells in El Refugio a TV documentation may be instructive. This could be combined with general maintenance when the pump is out.

Additionally observation wells should be drilled with continous determination of the groundwater table. At least half of these observation wells should be deep enough to reach the Cretaceous aquifer. The pumping rate of the well PSD should be checked again since it creates a deep depression cone in the surrounding groundwater table isolines. New pumping tests in observation wells with more information about the well equipment and a more detailed idea of geology are recommended.

For more exact calculation of the groundwater recharge meteorological stations in the Sierra are undeniable. Determination of chlorine concentrations in the precipitation may inable to calculate the groundwater recharge according to the salt balance method. However for El Refugio problems may occur due to the intensive agricultural use with man made chlorine input. The determination of bromide instead of chlorine would solve this problem. To start with a record of at least 2-3 years is necessary to eliminate seasonal variations. For further refining the idea about the recharge area, more isotope determinations (^{2}H, ^{18}O) are necessary, including isotope determination of rain water collected in the Sierra to eliminate altitude effects. The assumption that $\delta^{18}O$ concentration decreases by 2 ‰ with an increase of 1000 m altitude performed in this study is only a rough estimation. Time series of isotope determinations can eliminate seasonal variations

Hydrogeochemistry

For hydrogeochemistry already many analysis have been done, unfortunately mostly without considering geology or hydrogeological settings (especially different aquifers). Therefore only chemical analysis on main ions are not urgently required. Trace elements like Li, B, Ba, Al, Ni, Se and Sr should be checked again at least 3-4 times since they showed hugh differences between the July and October sampling. For a better understanding and modeling of the water-mineral interactions physicochemical analysis of precipitation samples would be helpful. Furthermore it would be interesting to analyse the "fault well", located next to the highway Rioverde-San Luis Potosi (W-100.07708; N 21.95805), build over a natural fracture zone suspected to be part of the western graben fault.

Determination of the water age would be very interesting. Especially for the karst system it could help to prove assumed differences in circulation depths between the deep wells in El Refugio and the karst springs. Due to the presumely young ages ^{14}C dating is not applicable; ^{3}H concentrations determined in this study were too low for reliable interpretation. ^{85}Kr determination would be possible; at the TU Freiberg right now a PhD study is performed to develop an equipment for ^{85}Kr determination in the field.

The critically high concentrations of pesticides, that were found in the drinking water wells P3, P9, P12 and Chilera, but also in P16 and P17, have to be checked again. More different pesticide substances than the ones analyzed in this study may be found, especially triazines are suspected from the growing an threating of mais. If these pesticide concentrations were confirmed well head protection zones would have to be outlined. Fortunately a zone 1 already exists with a fence of about 10x10m around the well head. Zone 2 would have to be established according to the 50-days-line, the distance, from which it takes 50 days for the groundwater to reach the well (time for pathogeneous bacteria to die). Restrictions have to include no transportation or handling with water endangering substances and restricted agricultural use, especially no application of pesticides. For the determination of the 50-days-line pumping tests will be necessary in order to determine groundwater flow velocity. An alternative to setting up protection zones would be to replace filter screens in the Quaternary sediments by casing in order to tap only Cretaceous groundwater.

The most important point certainly is to further improve sustainable GIS-based groundwater management centered in one administration preferably in Rioverde. All new investigators should have unrestricted access to existing data on the one hand and on the other hand should be obliged to contribute their results to a central database.

7. LITERATURE

A

AGGETT J. & KRIEGMANN M.R. (1987): Preservation of Arsenic (III) and Arsenic (V) in samples of sediment interstitial water; Analyst, Vol.112, S. 153-157.
AHMANN D., KRUMHOLZ L.R., HEMOND H.F., LOVLEY D.R. & MOREL F.M.M. (1997): Microbial Mobilization of Arsenic from Sediments of the Aberjona Watershed.- Environmental Science and Technology, Vol.31, No.10; S.2923-2930.
AL-SHAWI A.W., DAHL R. (1995): Determination of thorium and uranium in nitrophosphate fertilizer by ion chromatography.- Journal of Chromatography A, 706, p.175-181; Elsevier.
ALVARADO A.R. (1973): Estudio geohidrologico de la cuenca de Rio Verde, estado de San Luis Potosi.-Universidad Autonoma de San Luis Potosi, Escuela de Ingenieria.
ALVARADO PEDRAZA J.D. (1981): Condiciones geohidrologicas del manantial "La Media Luna" Municipio de Rioverde, San Luis Potosi.- Universidad Autonoma de San Luis Potosi, Escuela de Ingenieria.
APPELO C.A.J. & POSTMA D. (1993): Geochemistry, groundwater and pollution.- Balkema; Rotterdam.
ARMIENTA M.A., RODRIGUEZ R., AGUAYO A., CENICEROS N., VILLASEÑOR G. & CRUZ O. (1997): Arsenic contamination of groundwater at Zimapán, Mexico.- Hydrogeology Journal, Vol.5.No.2; S.39-46.
ARMIENTA M.A., RODRIGUEZ R., AGUAYO A., CENICEROS N., VILLASEÑOR G., JUÁREZ F. & MÉNDEZ T. (1993): Estudio de reconocimiento de la contaminación por Arsénico en la Zona de Zimapán, Hidalgo. Universidad Nacional Autónoma de México, Instituto de Geofisica; Mexico D.F.
ARMIENTA M.A., RODRIGUEZ R. & CRUZ O. (1997): Arsenic content in hair of people exposed to natural arsenic polluted groundwater at Zimapán, México.- Bulletin of environmental contamination and toxicology; Vol.59; S.583-589; Springer; New York.

B

BENJAMIN M.M. & HONEYMAN B.D. (1992): Trace Metals.- Global Biogeochemical Cycles, p.317-352; Academic Press Limited.
BIRKLE P., TORRES RODRIGUEZ V., GONZÁLEZ PARTIDA E. (1995): Effects of evapotranspiration on the water balance of the valley of Mexico.- Geofísica Internacional, Vol. 35, No.1, p.63-72.
BIRKLE P., TORRES RODRIGUEZ V., GONZÁLEZ PARTIDA E. (1995): The water balance for the basin of the valley of Mexico and implications for future water consumption.- Hydrogeology Journal, Vol. 6, p.500-517; Springer.
BIRKLE P. (1998): Herkunft und Umweltauswirkungen der Geothermalwässer von Los Azufres, Mexico.- Wissenschaftliche Mitteilungen, Heft 6; Institut für Geologie, Technische Universität Bergakademie; Freiberg.
BISSEN M., GREMM T., KÖKLÜ Ü. & FRIMMEL F. (noch unveröffentlicht): Use of the Anion-Exchange Resin Amberlite IRA-93 for the Separation of Arsenite and Arsenate in Aqueous Samples.- Acta Hydrochimica et Hydrobiologica.
BRAUN J.J., PAGEL M., HERBILLON A. & ROSIN C. (1993): Mobilization and redistribution of REEs and thorium in a syenitic lateritic profile: A mass balance study.-Geochimica et Cosmochimica Acta, Vol.57, p.4419-4434.
BUSHWAY R.J., PERKINS B., SAVAGE S.A., LEKOUSI S.J. & FERGUSON B.S. (1988): Determination of Atrazine Residues in water and soil by enzyme immunoassay.- Bull. Environ. Contam. Toxicol., Vol.40, p.647-654, Springer; New York.

C

CARDONA BENAVIDES, V. (1993): Proyecto ejecutivo para el manejo, tratamiento y disposicion de residuos solidos urbanos en Rio Verde, S.L.P. - Trabajo Recepcional que para obtener el titutlo de ingeniero civil. Universidad Autonoma de San Luis Potosi.
CARRILLO BRAVO J. (1971): La Plataforma Valles - San Luis Potosi: Bol. Aso. Mex. Geologos Petroleros., V.23, Nos.1-6, 102p.
CARSON B.L., ELLIS H.V:, McCANN J.L. (1986): Toxicology and biological monitoring of metals in humans - including feasibility and need.- Lewis Publishers. Inc; Chelsea.

CEBRIÁN M.E., ALBORES A., AGUILAR M. & BLAKELY E. (1983): Chronic arsenic poisoning in the north of Mexico.-Human Toxicology, Vol.2, S.121-133.
CETENAL (1970): Carta de climas de Queretaro, No.14 QIII
CETENAL (1976): Carta Topografica 1:50000, No. F14-C16 "El Refugio", No. F14-C17 "Rioverde", No. F14-A86 "San Francisco", No.F14-A87 "Angostura", S.L.P., Mexico
CETENAL (1976): Carta Geologica 1:50000, No. F14-C16 "El Refugio", No. F14-C17 "Rioverde", No. F14-A86 "San Francisco", No.F14-A87 "Angostura", S.L.P., Mexico
CETENAL (1983): Carta Geologica 1:250,000, No. F14-8 Ciudad Valles, No. F14-7 Guanajuato, No. F14-5 Ciudad Mante, No. F14-4 San Luis, Mexico.
CETENAL (1976): Carta Edafologica 1:50000, No. F14-C16 "El Refugio", No. F14-C17 "Rioverde", No. F14-A86 "San Francisco", No.F14-A87 "Angostura", S.L.P., Mexico
CETENAL (1976): Carta Uso Potencial 1:50000, No. F14-C16 "El Refugio", No. F14-C17 "Rioverde", No. F14-A86 "San Francisco", No.F14-A87 "Angostura", S.L.P., Mexico
CHAM AMARAL C. (1998): Estudio geohidrologico de las comunidades el Tecomates y la Tapona, Municipio de Rioverde, S.L.P.- Universidad Autonoma de San Luis Potosi, Escuela de Ingenieria.
CHAM AMARAL C. (1998): Estudio geohidrologico de las comunidades el Zapote, el Huizachal, las Magdalenas y la Loma-Buena Vista, Municipio de Rioverde, S.L.P.- Universidad Autonoma de San Luis Potosi, Escuela de Ingenieria.
CHAM AMARAL C. (1998): Estudio geohidrologico de las comunidades el Jabali, Municipio de Rioverde, S.L.P.- Universidad Autonoma de San Luis Potosi, Escuela de Ingenieria.
CHAM AMARAL C. (1998): Estudio geohidrologico de las comunidades el Zapote, la Muralla y Ojo de Agua de Solano, Municipio de Rioverde, S.L.P.- Universidad Autonoma de San Luis Potosi, Escuela de Ingenieria.
CLARK I.D. & FRITZ P. (1997): Environmental Isotopes in Hydrogeology.-Lewis Publishers.
COMISION FEDERAL DE ELECTRICIDAD (1984): Estudio de prospeccion geohidrologica en los aquiferos denomina dos de agua salada, en la zona Cerritos - Rio Verde, estado de San Luis Potosi.-Acuaplan, S.A. Contrato No. 831286.
COOK P.G. & SOLOMON D.K. (1997): Recent advances in dating young groundwater: chlorofluorocarbons, 3H/3He and 85Kr.-Journal of Hydrology; Elsevier Science; S.245-265.
COMISION NACIONAL DEL AGUA (1991): Caracteristicas generales; Manatial Media Luna Mpio.Rioverde, SLP.-prospect
CUTTER G.A. & CUTTER L.S. (1995): Behavior of dissolved antimony, arsenic and selenium in the Atlantic Ocean.-Marine Chemistry, Vol.49, Issue 4; Elsevier Science; S. 295-306.

D

DAS D., SAMANTA G., MANDAL B.K., CHOWDHURY T.R., CHANDA C.R., CHOWDHURY P.P., BASU G.K. & CHAKRABORTI D. (1996): Arsenic in groundwater in six districts of West Bengal, India.-Environmental Geochemistry and Health, Vol. 18, S. 5-15; Chapman & Hall.
DAVISSON M.L., SMITH D.K., KENNEALLY J. & ROSE T.P. (1999): Isotope hydrology of the southern Nevada groundwater: Stable isotopes and radiocarbon.-Water Resources Research, Vol.35, No.1, p.279-294.
DE LA PENA GAMEZ M.R. (1994): Investigaciones geologicas, mineralogicas e hidrogeoquimicas del area de Rio Verde, San Luis Potosi.- Tesis de la Universidad Autónoma de Nuevo León; Facultad de Ciencies de la Tierra; Linares.
DEUTSCH W.J. (1997): Groundwater Geochemistry: Fundamentals and Applications to Contamination.-Lewis Publishers; New York.
DIN EN 26595 (1992): Bestimmung von Arsen - Photometrisches Verfahren mit Silberdiethyldithiocarbamat.-Deutsche Einheitsverfahren zur Wasser-, Abwasser- und Schlammuntersuchung, 29. Lieferung, 1993.
DOF (1996): Diario Oficial de la Federacíon, Norma Oficial Mexicana NON-1127-SSAI-1994
DREVER J.J. (1997): The geochemistry of natural waters, 3.edition.- Prentice Hall; New Jersey, USA.
DRISCOLL F.G. (1986): Groundwater and wells, 2nd edition.-Johnson Division; Minnesota, USA.

E

EICK M.J., GROSSL, P., SPARKS D.L., GOLDBERG S. & AINSWORTH C.C. (1997): Arsenate and chromate retention mechanisms on goethite; 2. Kinetic evalutaion using a pressure-jump relaxation technique.-Environmental Science & Technology, Vol.31, No.2, S. 321-326.
EMSLEY J. (1992): The Elements, 2nd edition.-Oxford University Press; Newe York.

EPA Environmental Protection Agency (1984): Health Assessment Document for Inorganic Arsenic; EPA-600/8-83-021F.
EPA Environmental Protection Agency (1980): Ambient Water Quality Criteria for Arsenic; EPA-440/5-80-021.
EPA Environmental Protection Agency (1973): Water Quality Criteria, Ecological Research Series, Washington, D.C.

F

FENDORF S., EICK M.J., GROSSL, P. & SPARKS D.L. (1997): Arsenate and chromate retention mechanisms on goethite; 1. Surface Structure.-Environmental Science & Technology, Vol.31, No.2, S. 315-320.
FETTER C.W. (1999): Contaminant Hydrogeology, 2nd edition. Prentice Hall; New Jersey.
FOURNIER R.O. & POTTER II R.W. (1982): A revised and expanded silica (quartz) geothermometer.- Geothermal Resources Council Bulletin, 11, 3-9.

G

GRANAT L. (1976): Tellus, 24, 550.
GRAY D.M. (1973): Handbook of Principles in Hydrogeology.- Water Information Center Inc. Huntington, N.Y.
GREENWOOD & EARNSHAW (1990): Chemie der Elemente.-Verlag Chemie; Weinheim.
GULENS J., CHAMP D.R. & JACKSON R.E. (1979): Chemical Modeling in aqueous systems, Part 4: Influence of redox environments on the mobility of arsenic in ground water, ACS Symposium Series 93, American Chemical Society; Washington; S.81-95.

H

HARRINGTON J.M., FENDORF S.E., ROSENZWEIG R.F. (1998): Biotic Generation of Arsenic (III) in Metal(loid)-Contaminated Freshwater Lake Sediments.- Environmental Science and Technology, Vol.32, No.16; S.2425-2430.
HAUENSTEIN M. & HUTZLER-GARDT U. (1996): Bodenbelastungkataster Rheinland-Pfalz: Inventur der Gehalte an Spurenelementen und organischen Schadstoffen in Böden von Rheinland-Pfalz.- Geologisches Landesamt Rheinland-Pfalz; Mainz.
HEINRICHS G. (1996): Arsenkonzentrationen in Grundwässern.- Forschungsergebnisse aus dem Bereich Hydrogeologie und Umwelt, Heft 12; Uni Würzburg.
HENCKE J. (1998): Redoxreaktionen im Grundwasser: Etablierung und Verlagerung von Redoxfronten und ihre Bedeutung für die Spurenelement-Mobilität.- Bericht aus dem FB Geowissenschaften; Uni Bremen HB, 122 p.
HERCZEG A.L., LEANEY F.W.J., STADTER M.F., ALLAN G.L. & FIFIELD L.K. (1997): Chemical and isotopic indicators of point-source recharge to a karstic aquifer, South Australia.- Journal of Hydrology, Vol.192, p.271-299; Elsevier.
HERNANDEZ TORRES J.R. (1982): Descripcion Geologica del yacimiento de Fluorita El Refugio, Muncipio de Victoria, Gto.- Universidad Autonoma de San Luis Potosi, Escuela de Ingenieria.
HOCK B. (1989): Enzymimmunoassays zur Bestimmung von Pflanzenschutzmitteln im Wasser.- Z. Wasser-Abwasser-Forsch., 22, p.78-84, VCH VerlagsgesellschaftmbH; Weinheim.
HOFMANN M. (1994): Hydrogeologische und hydrogeochemische Untersuchungen an Grundwässern NE-Mexikos - unter besonderer Berücksichtigung hydrothermaler Spurenelementanreicherungen in Wasser und Gestein.- TU Bergakademie Freiberg, Unveröffentlichte Habilitationsschrift.
HOLM T.R., ANDERSON M.A., IVERSON D.G. & STANFORTH R.S. (1979):): Chemical Modeling in aqueous systems, Part 31: Heterogeneous Interactions of Arsenic in Aquatic Systems.- ACS Symposium Series 93, American Chemical Society; Washington; S.711-736.
HOLM T.R. & CURTISS C.D. (1989): A comparison of oxidation-reduction potentials calculated from As (V) / As (III) and Fe (III) / Fe (II) couples with measured platinum-electrode potentials in groundwater.- Journal of Contaminant Hydrology, Vol.5, Elsevier Science; Amsterdam. S. 67-81.

K

KATTAN Z. (1997): Environmental isotope study of the major karstic springs in Damascus limestone aquifer systems: case of the Figeh and Barada springs.- Journal of Hydrology, Vol.193, p.161-182; Elsevier.

KENDALL A.C. (1979): Continental and Supratidal (Sabkha) Evaporites: in Walker R.G. (1979): Facies Models. Geological Association of Canada Publications, Toronto; p. 145-157.
KORTE N.E. & FERNANDO Q. (1991): A Review of Arsenic(III) in Groundwater. Crit. Rev. Environ. Control., 21, 1-39.

L

LABARTHE G., TRISTAN M., AGUILLÓN A. & JIMÉNEZ L.S. (1989): Cartographia geologica 1:50 000 de las hojas El Refugio y Mineral El Realito, Estados de San Luis Potosi y Guanajuato.- Folleto Tecnico No.112; Universidad Autonoma de San Luis Potosi, Instituto de Geologia.
LABARTHE G., TRISTAN M. & ARANDA J. (1982): Revisión Estratigráfica del Cenozoico de la Parte Central del Edo. de S.L.P..- Folleto Tecnico No.80; Universidad Autonoma de San Luis Potosi, Instituto de Geologia.
LACAYO M.L., CRUZ A., CALERO S., LACAYO J. & FOMSGAARD I. (1992): Total Arsenic in Water, Fish and Sediments from Lake Xolotlán, Managua, Nicaragua.- Bulletin of environmental contamination and toxicology; Vol.49.No.3; S.463-470; Springer; New York.
LANDNER L. (1989): Chemicals in the aquatic environment - Advanced Hazard Assessment.-Springer; Berlin.
LARA GARCIA M.J. (1980): Evaluación Geologica del Deposito de Fluorita, Ubicado en la Mina "El Refugio", Muncipio de Victoria, Gto.- Universidad Autonoma de San Luis Potosi, Escuela de Ingenieria.
LAWA (1994): Länderarbeitsgemeinschaft Wasser: Empfehlungen für die Erkundung, Bewertung und Behandlung von Grundwasserschäden.- 19S.; Stuttgart.
LOPEZ RAMOS E. (1982): Geologia de México, Tomos II y III, 3ª edicíon. Secretaría de Educación Publica. No. 6402/79

M

MANNING B.A., FENDORF S.E., GOLDBERG S. (1998): Surface Structures and Stability of Arsenic (III) on Goethite: Spectroscopic Evidence for Inner-Sphere Complexes.- Environmental Science and Technology, Vol.32, No.16; S.2383-2388.
MARTIN M. (1996): "Seltene Elemente in Erzgebirgischen Grubenwässern" in: Grundwasser und Rohstoffgewinnung, Vortrags- und Posterkurzfassungen der Tagung der Fachsektion Hydrogeologie der DGG, B.Merkel, P.G.Dietrich, W-Struckmeier, E.P.Löhnert (Hrsg.).- Sven von Loga; Köln
MASSCHELEYN P.H., DELAUNE R.D., PATRICK W.H. (1991): Effect of redox potential and pH on arsenic speciation and solubility in a contaminated soil.-Environ.Sci.Technol., Vol.25, No.8; S. 1414-1419.
MATTHESS G. (1990): Die Beschaffenheit des Grundwassers, 2.Aufl.- Gebrueder Borntraeger; Stuttgart.
MEADE ALONSO J.R. (1971): Prospeccion y exploration geologica de la Tinaja, Municipio de Rioverde, San Luis Potosi.- Universidad Autonoma de San Luis Potosi, Escuela de Ingenieria.
MERKEL B. & SPERLING B. (1996): Hydrogeochemische Stoffsysteme, Teil I.- DVWK-Schriften, Bd. 110.; Komissionsvertrieb Wirtschafts- und Verlagsgesellschaft Gas und Wasser mbH, Bonn.
MERKEL B. & SPERLING B. (1998): Hydrogeochemische Stoffsysteme, Teil II.- DVWK-Schriften, Bd. 117.; Komissionsvertrieb Wirtschafts- und Verlagsgesellschaft Gas und Wasser mbH, Bonn.
MONTANEZ CASTRO A. (1992): Hidrogeoquimica del municipio de Rioverde, San Luis Potosi.- Universidad Autonoma de San Luis Potosi, Escuela de Ingenieria.
MORÁN-ZENTENO, D. (1994): Geology of the Mexican Republic. AAPG Studies in Geology #39. American Association of Petroleum Geologists; Tulsa, USA.
MORTIMER C. E. (1987): Chemie, 5.Aufl.- Georg Thieme Verlag; Stuttgart.

N

NAVARRO M., SÁNCHEZ M., LÓPEZ H. & LÓPEZ M.C. (1997): Arsenic contamination levels in waters, soils and sludges in Southeast Spain.- Bulletin of environmental contamination and toxicology; Vol.50.No.3; S.356-362; Springer; New York.
NEUHAUS A. (1994): Dissertation Erfassung und Quantifizierung von Quecksilber-, Arsen-, Antimonverbindungen im Bereich Boden-Pflanze eines historischen Quecksilber-Bergbaugebietes im Nordpfälzer Bergland; Uni Mainz.

NICOLLI H.B., SURIANO J.M., GOMEZ PERAL M.A., FERPOZZI L.H., BALEANI O.A. (1989): Groundwater contamination with Arsenic and other trace elements in an area of the pampa, province of Córdoba, Argentina, Environ.Geol.Sci.Vol.14, No.1, Springer Verlag; New York; S.3-16.
NIEDERLÄNDISCHE LISTE (1994): Leidraad Bodemsanering.- In: ROSENKRANZ D., BACHMANN G., EINSELE G., HARREß H.-M.: Bodenschutz, Ergänzbares Handbuch der Maßnahmen und Empfehlungen für Schutz, Pflege und Sanierung von Böden, Landschaft und Grundwasser, KZ 8935, 1-4; Berlin.
NORMA Oficial Mexicana NOM-127-SSA1-1994, Salud ambiental, agua para uso y consumo humano-Limites permisibles de calidad y tratamiento a que debe someterse el agua para su potabilización.-Comité Consultivo Nacional de Normalizacíon de Regulacíon y Fomento Sanitario.
NRIAGU J.O. (1994): Arsenic in the environment - Part I: Cycling and characterization.- Advances in Environmental Science and Technology; Bd.26.- John Wiley and Sons Inc.; New York.
NRIAGU J.O. (1994): Arsenic in the environment - Part II: Human Health and Ecosystem Effects.- Advances in Environmental Science and Technology; Bd.27.- John Wiley and Sons Inc.; New York.
NRIAGU J.O. (1998): Thallium in the environment.- Advances in Environmental Science and Technology; Bd.29.- John Wiley and Sons Inc.; New York.

P

PANCZNER W.D. (1987): Minerals of Mexico.-Van Nostrand Reinhold Company Inc.; New York.

R

RAISZ E. (1959): Landforms of Mexico; map 1:3,000,000.
RATHOD K.S. & RUSHTON K.R. (1990): Interpretation of pumping from two-zone layered aquifers using a numerical model.- ###, p.499-509.
REIMANN C., HALL G.E.M., SIEWERS U., BJORVATN K., MORLAND G., SKARPHAGEN H. & STRAND T. (1996): Radon, fluoride and 62 elements as determined by ICP-MS in 145 Norwegian hard rock groundwater samples.- The Science of the Total Environment, 192, p.1-19; Elsevier.
REMENIERAS G. (1974): Tratado de Hidrología Aplicada. Barcelona; Espana.
ROSAS I., BELMONT R., ARMIENTA A., BAEZ A. (1997): Arsenic concentrations in water, soil, milk and forage in Comarca Lagunera, Mexico.- Water, Air, and Soil Pollution Vol.112; S. 133-149; Kluwer Academic Publishers; Netherlands.
ROZANSKI K., ARAGUÁS-ARAGUÁS L. & GONFIANTINI R. (1993); Isotopic patterns in modern global precipitation. In: Continental Isotope Indicators of Climate, American Geophysical Union Monograph.
RÜDE T.R. (1996): Beiträge zur Geochemie des Arsens.-Karlsruher Geochemische Hefte, Schriftenreihe des Instituts für Petrographie und Geochemie, BandNr. 10, Karlsruhe.
RUIZ J., KESLER S.E., JONES, L.M., SUTTER J.F. (1989): Geology and Geochemistry of the Las Cuevas Fluorite Deposit, San Luis Potosi, Mexico.-Economic Geology, Vol.75, S.1200-1209.

S

SALOMONS W. & FÖRSTNER U. (1980): Environ.Technol.Lett, 1, p.506-517.
SANDHU S.S. & NELSON P. (1978): Ionic interference in the determination of arsenic in water by the silver diethyldithiocarbamate method.-Analytical Chemistry, Vol.50, No.2; S.322-325.
Schlussbericht für das Bayerische Landesamt für Wasserwirtschaft zum Forschungs- und Entwicklungsvorhaben Arsen und Eisenentfernung (TU München 1988)
SCOTT R.C. & BARKER F.B. (1962): Data on Uranium and Radium in Ground Water in the United States 1954 to 1957.- Geological Survey Professional Paper 426, United States Government Printing Office; Washington.
SECRETARIA DE ECOLOGIA Y GESTION AMBIENTAL (1998): Propuesta de proyecto para la caracterizacion y rescate de manatiales y humedales en el Valle de Rioverde; carta de localizacion de humedales en Rioverde.- unpublished.
SECRETARIA DE RECURSOS HIDRAULICOS, DIRECCION DE GEOHIDROLOGIA Y DE ZONAS ARIDAS (1972): Informe del estudio geohidrologico de evaluacion preliminar de la zona del Rio Verde en S.L.P.- Hidrotec S.A., Bucareli No.42 - 205, Vol. I

SECRETARIA DE RECURSOS HIDRAULICOS, DIRECCION DE GEOHIDROLOGIA Y DE ZONAS ARIDAS (1972): Informe del estudio geohidrologico de evaluacion preliminar de la zona del Rio Verde en S.L.P.- Hidrotec S.A., Bucareli No.42 - 205, Anexos Vol. II

SECRETARIA DE AGRICULTURA Y RECURSOS HIDRAULICOS, DIRECCION DE GEOHIDROLOGIA Y DE ZONAS ARIDAS (1980): Trabajos complementarios del estudio geohidrologico de la zona de Rio Verde, S.L.P.-Proyesco S.A.

SECRETARIA DE AGRICULTURA Y RECURSOS HIDRAULICOS, DIRECCION DE GEOHIDROLOGIA Y DE ZONAS ARIDAS (1980): Trabajos complementarios del estudio geohidrologico de la zona de Rio Verde, S.L.P.-Proyesco S.A., Anexos.

SECRETARIA DE AGRICULTURA Y RECURSOS HIDRAULICOS, Delegacion estatal en San Luis Potosi, Jefatura del Programa Hidraulico (1986): Configuracion de evolucion del nivel estatico 1980-1986, Valle de Rioverde. (only map)

SECRETARIA DE AGRICULTURA Y RECURSOS HIDRAULICOS, representacion gral. en el estado de San Luis Potosi, jefatura de unidades de riego No.705, residencia de geohidrologia y de zonas aridas (1984): sin titulo (caracteristicas de pozos exploratorio en el estado de San Luis Potosi con mapa de localizacion).

SUN X. & DONER H.E. (1998): Adsorption and oxidation of Arsenite on Goethite.-Soil Science Vol.163, No.4; Williams & Wilkins, USA.

T

TACSA (1998): Plan maestro para el mejoramiento de la Efficiencia del Organismo operador Rioverde, S.L.P. - Contrato APA-IHU-SLP-96-01.

TERTILT K. & MERKEL B. (1993): Simulation der Grundwassergefährdung mit Hilfe hybrider GIS-Technologie. Geo-Informations-Systeme, Vol.6, No.4, p.1-6.

THOMAS J.E. & RHUE R.D. (1997): Volatilization of Arsenic in Contaminated Cattle Dipping.- Bulletin of environmental contamination and toxicology; Vol.59.No.3; S.882-887; Springer; New York.

TOKUNAGA S. , WASAY S. A. & PARK S.W. (1997): Removal of Arsenic(V)ion from aqueous solutions by Lanthanum compounds.- Water Science and Technology, 35, 7, 71-78.

TrinkwV (1990): Verordnung über Trinkwasser und Wasser für Lebensmittelbetriebe (Trinkwasserverordnung vom 5.Dezember 1990).- BGB1.I, S. 2612-2629; Bonn.

TUTA Z.H., SUTTER J.F., KESLER, S.E. & RUIZ J. (1988): Geochronology of Mercury, Tin, and Fluorite Mineralization in Northern Mexico.- Economic Geology, Vol.83, p.1931-1942.

U

US SALINITY LABORATORY STAFF (1954): Diagnosis and Improvement of Saline and Alkali Soils. USDA, Agricultural Handbook, No.60; Washington.

V

VAN ELTEREN J.T., HOEGEE J., VAN DER HOEK E.E., DAS H.A., DE LIGNY C.L. & AGTERDENBOS J: (1991): Preservation of As(III) and As(V) in some water samples.- J. Radioanal. Nucl. Chem., Letters 154 (5), p.343-355; Elsevier, Lausanne.

VOLKE P. & MERKEL B. (1997): A field method of spectrophotometric determination of arsenic in water including a speciation.- in Field Screening Europe: Proceedings of the first international conference on strategies and techniques for the investigation and monitoring of contaminated sites. edited by GOTTLIEB J., HÖTZL H., HUCK K. & NIESSNER R.; Kluwer Academic Publishers; Netherlands, p.371-375.

VOLKE P. & MERKEL B. (1999): Anwendung eines neuen Feldanalysenverfahrens zur Untersuchung der Stabilität von Arsen und seinen anorganischen Spezies in aquatischen Systemen.- Acta hydrochim.hydrobiol.27, p.230-238. Wiley; Weinheim.

W

WELCH A.H., LICO M.S., HUGHES J.L. (1998): Arsenic in ground water of the Western United States.- Groundwater, Vol. 26 No.3, S. 333-347.

WILSON B.W., HERNANDEZ, J.P. & MEAVE T.E. (1955): Un Banco Calizo del Cretácico de la Parte Oriental del Edo. de Querétaro.- Bull.Soc.Geol.Mexicana, V.18, p.1-10.

WITHERS B., VIPOND S. & LECHER K. (1978): Bewässerung, 1. Aufl.; Paul Parey Verlag.

WHO World Health Organisation (1993): WHO Guidelines for Drinking Water Quality, Vol.2. Health Criteria and Other Supporting Information. WHO, Geneva, Switzerland.

WHO World Health Organisation (1996): WHO Guidelines for Drinking Water Quality, Vol.2, 2nd edition. Health Criteria and Other Supporting Information. WHO, Geneva, Switzerland.

Z

ZEIL W. (1990): Brinkmanns Abriß der Geologie, Erster Band: Allgemeine Geologie, 14. Aufl.-Enke Verlag; Stuttgart.

Internet

Periodical table of elements
http://www.shef.ac.uk/~chem/web-elements/
http://www.uniterra.de/rutherford/

Arsenic in Asia
http://www.kfunigraz.ac.at/fwiwww/aan/asiahome.html

Fluoride and Arsenic Society of China
sungf@iris.cmu.edu.cn

Groundwater Arsenic Research Group, Stockholm
http://www.ce.kth.se/aom/AMOV/PEOPLE/Prosun/garg.htm

Arsenic Contamination in the world
http://www.who.int/peh-super/Oth-lec/Arsenic/Series2/003.htm

Mexican Mining Information Center
http://www.mexmin.com/

Mexican Maps Center
http://www.inegi.gob.mx

San Luis Potosi - Rioverde
http://200.36.12.238/rioverde/rioverde.htm
http://www.anglefire.com/ok/Sanluis/slpmap.html

1. BACKGROUND

App.No.1.: Meteorological data from the Rioverde station (N 21°55´30´´, W 99°58´44´´)

month	average Temp. [°C]	max. Temp. [°C]	min. Temp. [°C]	precipitation [mm]	number of rain events (>1mm rain)	vapor tension [hPa]	insolation [h.min]	air pressure [mbar ASL]	potential evaporation	dew point [°C]	humedad [%]
Jan 80	15.6	30	4.6	22.7	6	13.4	183.56	1014.9			77
Feb 80	15.3	34.6	0.6	12	4	11.8	217.5	1016.3			71
Mrz 80	20.3	38.2	1.8	1.2	3	14.2	245.35	1009.8			63
Apr 80	20.9	38.6	6	8.2	0	14.7	162.59	1010.7			63
Mai 80	25.7	40.4	15.4	81.8	7	20.3	253.39	1005.9			66
Jun 80	24.9	35.6	16.5	3.9	1	19.8	199.43	1011			66
Jul 80	25.1	36.6	16.1	9.3	2	19.3	283.23	1010.9			63
Aug 80	24.3	38	16.5	15.5	6	20.4	255.39	1009.7			71
Sep 80	23	36	14.8	113.1	11	---	176.12	1010.5			---
Okt 80	19.3	34.6	7.2	21.8	4	17.7	193.2	1014.8			79
Nov 80	15.5	31.9	1.6	3.6	5	13.5	141.23	1023.3			81
Dez 80	14.8	27.8	2	18.1	3	13.6	213.1	1019.7			78
Jan 81	13.2	29	0.4	47.2	6	11.7	141.55	1018.5			69
Feb 81	16.2	33.2	4.1	9.5	4	13.2	143.8	1017			73
Mrz 81	19.2	37.2	9.8	9	3	14.3	202.3	1012.2			66
Apr 81	21.8	37	11.5	146.2	5	18.2	188.21	1011.9			---
Mai 81	23.8	38.8	10.3	78.7	7	19.8	245.52	1007.6			70
Jun 81	23.8	38	17.5	103.1	13	22	198.16	1008.1			78
Jul 81	23.1	34	15.6	74.1	6	20.9	244.57	1012			76
Aug 81	23.1	35.3	16	60.8	6	20.2	232.4	1010.9			74
Sep 81	21.8	35.2	10.5	91.1	11	19.9	214.18	1012.8			79
Okt 81	20.8	33.6	11.7	25.5	8	19.4	192.26	1013			81
Nov 81	16.9	32.2	3	0.2	0	13	243.43	1016			69
Dez 81	16.2	32	5.4	15.9	3	13.6	159.48	1015.7			77
Jan 82	15.9	32.5	-1	2.2	0	12.1	224.2	1020.5			69
Feb 82	17.3	34	5.3	11.6	4	12.8	183.37	1018.3			71
Mrz 82	21.4	37.8	1.2	26.6	1	15.1	235.06	1010.4			65
Apr 82	24.5	41	13	123.6	4	18.1	170.21	1013.5			66
Mai 82	24	39	16.6	57.9	8	21.5	156.32	1012			77
Jun 82	25.9	40.2	15.8	---	0	19.8	299.19	1012.8			65
Jul 82	24.3	36.5	15.1	19.2	4	19.1	274.16	1016.7			67
Aug 82	24.3	34.9	15.6	13.9	4	18.8	249.07	1014.5			68
Sep 82	22.8	36.4	11.6	57.4	4	19	206.01	1013.9			74
Okt 82	20.2	32.6	8.3	73.5	7	17.8	194.17	1016			---
Nov 82	17.5	31.4	2.6	19.8	4	14.8	184.16	1017.4			78
Dez 82	15.4	31.4	-1	30.5	6	12.4	143.12	1018.2			80
Jan 83	14.7	32	3.2	15.8	6	12.2	142.42	1018.1			---
Feb 83	17.1	31	2.5	2.1	1	11.4	221.43	1012.8			65
Mrz 83	19.8	37.2	6.3	1.5	2	11.6	281.24	1010.1			56
Apr 83	22.2	40.8	6.5	0.1	1	13.4	275.28	1009.2			55
Mai 83	25.7	42.8	11.7	47	4	19.7	243.33	1008.4			66
Jun 83	25.9	39.4	16	13.2	2	20.4	273.06	1009.9			67
Jul 83	23.7	33.3	15	133.1	12	20.9	147.34	1014.8			78
Aug 83	23.7	35	14.3	23.4	4	20.3	248.1	1015.2			---
Sep 83	22.9	35	13.8	69.4	9	20.2	182.53	1014.4			78
Okt 83	20.6	32.4	8	21.4	3	17.9	213.35	1016.7			77
Nov 83	19.8	24.8	6	22.7	4	15.4	224.33	1014.6			73
Dez 83	16.3	33	-0.4	0.1	0	12.8	176.23	1018.9			72
Jan 84	14.5	30.6	1.4	32.3	5	12.3	131.09	1020.2			78
Feb 84	16.1	33.7	4	11.1	3	12.1	141.43	1016.9			72
Mrz 84	20	36.8	7.2	0.3	0	12.4	249.32	1013.1			59

month	average Temp. [°C]	max. Temp. [°C]	min. Temp. [°C]	precipitation [mm]	number of rain events (>1mm rain)	vapor tension [hPa]	insolation [h.min]	air pressure [mbar ASL]	potential evaporation	dew point [°C]	humedad [%]
Apr 84	24.3	41	9.9	0	0	13.1	291.14	1009.2			49
Mai 84	23.9	40.6	9.5	56.6	7	15.2	235.07	1012			64
Jun 84	24.4	39.5	11.5	48.9	8	20	269	1012			71
Jul 84	22.3	33.4	15.7	138.5	17	20.3	160.27	1013.6			80
Aug 84	22.8	34	13.8	79.4	9	19.9	223.28	1013.3			74
Sep 84	20.8	33.9	14.4	155.4	20	20	101.43	1013.8			85
Okt 84	22	35.3	13.9	2.1	1	19.3	214.33	1018.2			77
Nov 84	17.3	31.7	4.8	2.8	1	13.9	208.02	1018.5			76
Dez 84	17.5	29.6	6.4	15.9	4	14.4	171.01	1017.4			77
Jan 85	14.1	33.5	-2.6	3.4	2	11.1	177.5	1019.8	112.6	8.1	73
Feb 85	17.2	33.3	4.5	1.9	1	12.5	175.54	1017	119.11	9.9	69
Mrz 85	20.9	37.4	11.2	1.1	1	14.7	231.25	1014.1	104.41	12.6	66
Apr 85	22.3	37	7.4	172.4	10	17	207.44	1012.9	166.47	14.7	70
Mai 85	24.3	38.5	14	34.5	4	19.6	274.33	1010.9	189.97	17.2	70
Jun 85	23.9	38.3	15.2	111.7	12	20.4	210.56	1011.8	194.62	17.9	73
Jul 85	22.5	32.3	14.3	242.9	15	20	185.04	1014.3	140.51	17.6	78
Aug 85	23.9	33.8	15.8	44.4	7	20.4	286.47	1001.3	177.45	18	73
Sep 85	23.1	34.5	15.7	40.1	6	19.7	250.48	1013.7	149.84	17.4	75
Okt 85	22.4	33.2	9.2	2.8	1	18.5	244.34	1014.4	143.83	16.2	74
Nov 85	19.7	33.8	4.4	33.5	2	15.8	235.44	1015.1	110.28	13.6	74
Dez 85	17.6	30.4	1.4	7	3	13	169.2	1020.9	73.08	10.6	74
Jan 86	14.9	30.5	-2.1	---	0	10.4	227.59	1021.8	106.24	7.2	68
Feb 86	18.6	35.8	4.5	0.3	0	10.9	237.3	1014.8	130.59	7.7	58
Mrz 86	19.7	37.4	4	---	0	12.2	272.58	1015.2	172.35	9.3	58
Apr 86	23.8	39.8	11.4	133.9	7	18	232.23	1011.6	184.82	15.7	67
Mai 86	24.8	39.7	14.8	23.7	2	20.2	252.35	1009.4	199.39	17.6	70
Jun 86	23.5	35.5	16.7	49.2	7	18.5	209	1011.9	143.86	21.1	75
Jul 86	23.3	35.2	15.5	85.9	10	19.9	232.06	1015.3	172.59	17.5	74
Aug 86	24.8	35.5	16	10.1	2	19.4	301.45	1012.9	204.07	17.1	67
Sep 86	23.4	34.9	14.7	31.7	8	20.5	209.54	1013.7	136.93	18	76
Okt 86	20.6	33.8	7	81.6	8	18.6	153.14	1015.5	98.09	16.2	75
Nov 86	19.2	33.1	4	45	7	17.1	186.15	1015.5	109.46	14.9	77
Dez 86	16.2	31	7	14.9	1	13.7	162.25	1017.9	77.3	11.5	76
Jan 87	14.1	33.8	-0.1	7.3	2	10.5	206.2	1010.8	86.22	7.5	68
Feb 87	16.5	36	-3.9	2.3	1	12	174.36	1014.4	104.38	9.6	66
Mrz 87	18.8	37.9	0.9	3.8	1	14	193.8	1012.1	145.75	11.7	67
Apr 87	20.1	37.1	1	16.8	3	15.3	170.08	1013.9	141.34	12.8	65
Mai 87	23.9	37.2	11.4	35.1	5	24.9	234.43	1010.6	180.98	6.6	66
Jun 87	24.9	37.9	16.9	68.8	6	21.2	250.52	1011.5	169.7	18.6	71
Jul 87	23.2	34.8	17.1	185.5	18	21.2	209.46	1013.5	154.29	18.6	77
Aug 87	24.6	36.1	17.2	10	3	20.3	278.27	1012.9	184.2	17.8	64
Sep 87	23.8	35.8	14.7	38.8	6	20.7	209.23	1012.8	152.67	18.2	70
Okt 87	19	33	8.7	8.3	3	20.5	249.14	1018.1	138.53	13.6	70
Nov 87	17.4	32.3	6.4	13.2	2	14.5	191.14	1016.9	100.84	12.3	73
Dez 87	17.1	33.3	2.6	0.1	0	13.4	169.1	1016.4	73.1	11	67
Jan 88	14.1	---	---	5.1	1	11.1	166.23	1020.2	88.51	8.4	69
Feb 88	16.6	36.2	2	2.3	1	13.5	175.5	1017.6	101.59	10.7	66
Mrz 88	18.9	35.5	5.9	23.5	4	14.1	219.45	1014.4	145.34	12	64
Apr 88	23.2	39.3	9.1	28.9	5	17.1	216.4	1009.7	171.06	14.7	61
Mai 88	24.6	38.9	15.3	54.1	2	20.4	228.08	1010.2	179.97	17.8	67
Jun 88	24.7	38	17.4	62.4	12	20.8	147.37	1011	174.4	18.2	66
Jul 88	24	35.6	17.3	59.3	---	21.1	194.55	1013.34	148.78	18.4	70
Aug 88	22.7	34.4	16.8	166	12	21.8	205.11	1011.34	195.8	19	74
Sep 88	22.3	33.2	11.5	38.4	5	19.4	201.37	1011.24	134.63	17.2	71
Okt 88	20.1	33.1	11	9.1	3	17	162.14	1016.02	111.48	14.9	70
Nov 88	18.8	34.9	4.5	----	0	13.8	189.32	1014.77	109.84	11.2	61

month	average Temp. [°C]	max. Temp. [°C]	min. Temp. [°C]	precipitation [mm]	number of rain events (>1mm rain)	vapor tension [hPa]	insolation [h.min]	air pressure [mbar ASL]	potential evaporation	dew point [°C]	humedad [%]
Dez 88	16	30.6	4	2	1	13.1	91.51	1019.52	75.67	11	72
Jan 89	17.9	32.4	7.5	3	1	14.6	130.51	1016.79	86.13	12.5	70
Feb 89	17.1	36.1	1.8	6	3	12.7	156.15	1018.6	98.01	10	65
Mrz 89	19.3	36.3	-1	---	0	10.8	267.12	1012.79	182.87	7.2	48
Apr 89	21.8	36.9	10.1	49.4	8	15	236.19	1011.96	171.89	12.8	57
Mai 89	25.3	39.9	15.6	4.2	2	18.2	294.27	1009.11	206.28	15.9	57
Jun 89	25.1	41.6	13.6	92.2	6	19.8	262.11	1010.9	190.11	17.3	61
Jul 89	24.2	37.3	17	17	5	19.4	261.5	1013	169.55	16.9	63
Aug 89	18.9	36	17.3	143.4	17	20.9	51.28	1011.71	152.65	18.2	75
Sep 89	21	33.5	10	75.2	6	18.4	197.53	1012.84	121.96	16.2	71
Okt 89	19.3	33.4	5	2	1	15.2	200.01	1016.5	118.26	13.1	66
Nov 89	19.1	35.1	5	3.8	1	15.5	141.2	1014.58	87.12	13.2	69
Dez 89	13.1	30.2	-3.2	26.9	4	11	89.29	1019.34	73.5	14.6	74
Jan 90	16.5	31.2	6	10.3	2	12.9	78.29	1016.63	69.2	11.5	68
Feb 90	18.8	33.8	3.6	6.2	1	12.5	129.16	1014.61	75	9.6	56
Mrz 90	20.4	35.7	6.5	11.5	2	13.9	175.27	1014.07	122	11.5	61
Apr 90	23.1	39.8	10.8	1.3	0	16.6	221.14	1010.75	164.17	13.5	61
Mai 90	25.1	41.8	11.8	39.8	7	19.3	250.33	1007.84	190.64	17.4	60
Jun 90	25.1	37.5	16.2	26.7	5	19.7	268.25	1010.94	183.22	17.3	63
Jul 90	23.8	35.5	17	31.4	9	19.6	225.38	1013.31	97.81	17.9	70
Aug 90	23.3	33.3	14.4	176.9	12	20.3	222.19	1014.62	149.32	18.4	75
Sep 90	22.3	33.7	16.4	119.1	10	21.3	161.1	1013.34	112.42	18.7	80
Okt 90	19.8	32	8.1	92	8	18.3	146.23	1015.94	92.94	15.8	80
Nov 90	18	32.5	6.9	12	3	15.9	143.24	1017.35	83.98	13.8	75
Dez 90	14.9	33	-0.6	---	0	11.4	126.57	1018.52	85.06	8.4	70
Jan 91	17.2	32.2	4.5	1.8	1	13.4	105.38	1016.23	76.7	11.5	72
Feb 91	17.2	34.5	6.3	8.5	3	12.8	132.56	1019.74	95.46	10.3	71
Mrz 91	22.3	41.1	3.7	0.1	0	14.6	232.59	1009.77	181.41	10	53
Apr 91	25.5	41.2	12.6	3.9	1	16.3	239.15	1005.93	192.09	13.8	56
Mai 91	26.2	39.7	16	36.2	4	20.5	262.1	1007.6	189.39	18.6	65
Jun 91	24.9	38	17	99.3	7	20.8	206.2	1010.43	154.02	18.1	57
Jul 91	22.4	34.1	15.6	264	13	21.8	151.16	1014.24	116.77	18.9	79
Aug 91	24	34.6	15.3	27.7	6	19.8	233.35	1014.11	154.81	18	72
Sep 91	21.1	35.4	11.9	154.3	15	19.7	133.13	1014.39	107.07	17.3	78
Okt 91	20.1	32.6	5.5	66.8	7	18.1	145.25	1014.82	81.22	16.3	79
Nov 91	16.6	31.8	4.3	2.8	1	13.7	97.52	1018.04	80.04	11.3	72
Dez 91	16.4	32.5	6.9	19.6	4	14.4	57.56	1018.39	53.98	12.7	79
Jan 92	17.1	32	6	65.2	7	12.5	48.54	1018.04	54.35	10.4	54
Feb 92	17.1	31.8	5	6	2	17.5	167.08	1014.22	94.13	10.4	68
Mrz 92	21.5	37.9	9.5	14.6	2	15.6	176.11	1012.16	126.04	13.7	66
Apr 92	21.6	37	10	82.1	5	16	181.12	1011.8	139.63	8.9	66
Mai 92	21.7	33.7	14.1	101.6	10	18.6	196.25	1011.93	138.29	16.9	70
Jun 92	25.1	39.5	14.3	38.2	4	19.6	264.4	1008.86	167.26	17.1	66
Jul 92	23.5	38.8	16.5	74	11	19.7	207.15	1013.27	137.9	17.9	70
Aug 92	24.8	34.2	16.2	64.8	7	20.3	236.45	1013.75	135.09	18.5	70
Sep 92	21.9	34.5	11.2	50.3	8	20.7	163.57	1012.73	112.21	18.1	75
Okt 92	20	31.5	6.9	95.1	10	19.3	121.2	1014.57	76.7	17.3	79
Nov 92	17.4	31.8	0	8.8	2	16.3	115.26	1016.57	74.07	13.8	77
Dez 92	18.3	31.7	3.2	12.2	2	16	99.58	1016.06	65.72	14.4	76
Jan 93	17.4	32	5.5	3	2	14.4	102.35	1016.77	82.32	12.6	72
Feb 93	18.7	35.2	5.3	3.9	0	13.2	158.58	1014.55	103.38	10.6	65
Mrz 93	20	39.7	1.4	0.1	0	13.1	224.39	1013.88	150.6	10.9	63
Apr 93	22.7	37.7	9.2	9.9	2	13.9	73.32	1009.5	158.95	17.6	54
Mai 93	23.8	37.5	12.2	83.5	6	18.1	237.24	1002.25	169.32	16.1	62
Jun 93	24.1	40.5	14.8	195.4	16	20.7	153.02	1009.86	120.1	18.2	73
Jul 93	23.5	33.3	17.6	57.3	9	20.6	208.55	1014.17	133.44	18.7	73

month	average Temp. [°C]	max. Temp. [°C]	min. Temp. [°C]	precipitation [mm]	number of rain events (>1mm rain)	vapor tension [hPa]	insolation [h.min]	air pressure [mbar ASL]	potential evaporation	dew point [°C]	humedad [%]
Aug 93	23.6	33.6	15.9	78	5	19.7	210.16	1013.52	145.78	18.5	69
Sep 93	22.4	34	12.6	292.8	14	20.5	146	1013.29	95.77	17.9	76
Okt 93	20.3	33	5.7	49.6	3	18	181.17	1014.09	100.78	16.1	72
Nov 93	17.6	31.2	4.3	20.7	5	15.7	95.26	1016.93	59.96	13.5	75
Dez 93	16.3	31.5	-0.9	0.9	0	13.1	89.55	984.68	61.6	11.5	72
Jan 94	16	33.4	-0.5	15.8	3	12.8	110.18	1018.61	70.79	10.4	72
Feb 94	18.5	33.7	5.7	1.9	0	13.7	147.28	1015.18	94.31	11	67
Mrz 94	20.4	38.6	7.9	3.6	1	13.7	201.91	1013.01	146.91	11.4	61
Apr 94	22.7	38.2	9.9	67.4	6	17.5	191.07	1011.12	132.06	15.2	65
Mai 94	24.9	38.6	15.2	27.2	5	20.7	200.09	1009.89	156.52	18	65
Jun 94	25	36.2	16	61.7	10	21.6	217.13	1010.22	151.79	18.7	66
Jul 94	25.4	36.9	15.2	8.5	3	20.8	266.02	1012.32	176.16	18.1	63
Aug 94	24.1	35.3	14.8	72.4	10	21.6	209.47	1012.37	143.31	18.8	69
Sep 94	22.5	33.7	13.1	86.9	9	19.7	177.14	1013.38	112.68	17.4	70
Okt 94	22	36.2	9.9	73	5	20	155.15	1011.38	102.67	17.4	73
Nov 94	20.3	33.5	9.8	5.1	2	17.7	131.57	1014.47	82.78	15.4	73
Dez 94	18	30.4	5	1.7	0	15	103.11	1016.34	67.09	13.2	70
Jan 95	16.1	32.2	5.3	6.7	2	12.3	105.13	1017.05	74.34	10.1	68
Feb 95	13.2	34.8	3.4	1.2	1	14	182.16	1015.8	108.66	11.4	61
Mrz 95	21.4	40.3	5	0.3	0	15.8	209.59	1010.59	156.59	13.6	60
Apr 95	23.9	39.5	8.2	0.6	0	17.3	213.25	1007.33	167.41	14.9	57
Mai 95	27.6	41.7	17	10.4	1	22.5	209.59	1003.19	188.45	19.3	59
Jun 95	26	41	16.2	15	3	21.7	208.48	1008.92	158.45	18.8	63
Jul 95	24.7	37.7	15.9	28	8	19.6	220.5	1012.52	148.98	17.2	64
Aug 95	23.9	37.7	16.5	158.8	15	22.2	177.2	1009.67	111.96	18.5	71
Sep 95	23.7	33.7	15	4	8	22.1	176.44	1012.42	109.55	19.3	76
Okt 95	21.1	34.8	5.5	36.3	4	18	204.39	1012.56	117.71	15.7	67
Nov 95	18.9	33.4	3	16.5	3	16.2	150.04	1016.84	82.8	14	70
Dez 95	15.9	31.5	5	11.7	2	13.4	100.32	1030.3	66.19	11.4	75
Jan 96	15.1	32.1	0	1.6	1	10.5	231.28	1017.72	95.07	7.1	65
Feb 96	17.8	35.1	9	6.1	2	12.3	189.33	1015.54	100.38	9.7	62
Mrz 96	19.2	37.3	9.7	1.6	1	12.9	196.54	1015.29	147.98	10.5	62
Apr 96	21.1	38.8	12.1	4.3	1	15.9	241.5	1011.36	154.35	13.4	59
Mai 96	26.2	40	17	2.8	2	22.4	223.52	1008.29	148.95	19.3	62
Jun 96	25.1	37.9	17.6	91.2	5	23.3	179.07	1010.33	147.59	20	69
Jul 96	25.5	35.8	17.5	73.9	4	21.4	250.05	980.1	169.12	19.2	65
Aug 96	23.5	35.7	17.5	117	9	21.4	199.49	1012.68	124.39	18.6	71
Sep 96	23.6	31	17.1	87.4	8	22.6	170.05	1010.45	112.94	19.4	74
Okt 96	21.2	28.5	14.9	19.5	5	18.7	149.12	1013.62	95.45	16.6	74
Nov 96	18.5	32.6	11.1	11.4	4	14.8	101.18	1017.53	80.37	12.6	72
Dez 96	16.2	31.5	8.1	1.1	1	13.2	155.41	1018.04	76.28	10.4	72
Jan 97	16	33.4	3.9	7.8	1	12.9	182.98	1017.25	82.4	10.2	71
Feb 97	18	36	0.8	13.7	1	15.6	99.44	1015.22	99.44	13.3	73
Mrz 97	21	37.2	7.8	50.8	6	17.5	209.19	1014.1	123.13	15.9	71
Apr 97	21.3	37.8	10.4	86	8	19.1	189.41	1010.02	127.14	16.6	72
Mai 97	23.1	38.4	14.8	127.9	12	21.1	225.42	1012.06	141.59	18.4	73
Jun 97	25.5	39.2	17.4	26.4	4	21	226.4	1008.63	151.58	20.5	71
Jul 97	24.8	34.7	16.6	19.9	3	23.8	238.31	1012.63	142.06	20.3	73
Aug 97	25	36.5	17.5	15.6	4	18.8	250.28	1012.38	161.8	17.4	57
Sep 97	23.9	36	12	12.8	4	19.3	173.48	1011.82	115.25	16.9	65
Okt 97	20.3	33.5	5.8	90.1	8	16.5	179.3	1012.7	96.97	13.9	65
Nov 97	20.1	34.2	10	13.7	3	16.3	149.11	1013.84	74.33	14.2	70
Dez 97	14.6	34	-5	0.7	0	10	176.51	1016.08	68.98	6	60
Jan 98	17.8	31.8	6.4	18.4	1	11.4	208.14	1013.78	93.01	8.9	60
Feb 98	19.2	34.8	1.7	0	0	9.3	231.17	1009.56	129.47	5	45
Mrz 98	20.1	38.7	6	2.1	0	11.5	230.19	1011.37	148.4	8.5	51

month	average Temp. [°C]	max. Temp. [°C]	min. Temp. [°C]	precipitation [mm]	number of rain events (>1mm rain)	vapor tension [hPa]	insolation [h.min]	air pressure [mbar ASL]	potential evaporation	dew point [°C]	humedad [%]
Apr 98	23.5	43.1	10.5	---	0	---	250.48	1009.16	182.29	11.8	48
Mai 98	27.2	43.6	13.5	1.3	1	16.4	303.48	1007.32	197.5	14	44
Jun 98	28.1	42.9	18.9	12.4	4	19.9	265.33	1008.02	187.35	17.3	52
Jul 98	25.8	38.9	17.6	26.4	4	19.9	266.05	1012.18	158.57	17.4	60
Aug 98	25.2	35.5	16.7	84	6	21.9	229.04	1012.49	146.52	18.9	68
Sep 98	24.1	34.8	18.6	253.8	15	25.2	134.08	1007.6	107.29	21.3	82
Okt 98	20.9	32.2	11.5	124.8	13	22.2	122.29	1014.03	73.85	19	86
Nov 98	20.2	30.5	10.2	29.4	3	20.6	143.23	1014.8	65.5	17.4	83
Dez 98	16.8	30	10	0.2	0	13	191.2	1018.65	65.22	10.9	69
Jan 99	15.6	36.2	2.1	---	0	9.5	223.02	1018.53	83	5.7	56
Feb 99	18.6	34.2	-3	0.1	0	12.3	181.32	1016.47	93.63	9.9	55
Mrz 99	21.9	36.9	7.5	18.8	1	13.9	264.13	1011.41	157.11	11.4	55
Apr 99	24.9	40.7	11.5	3.5	1	14.8	239.33	1009.31	157.78	12.1	52
Mai 99	26.8	41.5	15.2	39.2	1	16.1	286.38	1008.14	195.24	13.6	46

App.No.2.: Meteorological data from Ojo de Agua Seco and Pastora station

	Ojo de Agua Seco					**Pastora**				
month	average temp. [°C]	max. temp. [°C]	min. temp. [°C]	precipitation [mm]	pot. evaporation	average temp. [°C]	max. temp. [°C]	min. temp. [°C]	precipitation [mm]	pot. evaporation
Jan 61	14.4	19.3	9.5	20	---					
Feb 61	17.3	25.4	9.2	13	---					
Mrz 61	22.9	30.2	15.5	0	---					
Apr 61	23.7	31.7	15.7	0.1	---					
Mai 61	26.2	33.2	19.3	0.8	---					
Jun 61	24.2	29.3	19.2	215	---					
Jul 61	23.3	28.2	18.4	97.5	---					
Aug 61	23.9	29.9	17.8	14.5	---					
Sep 61	23.6	29.1	18.1	85	---					
Okt 61	20.1	26.4	13.8	14.5	---					
Nov 61	19.2	25	13.4	16.5	---					
Dez 61	18.8	25.6	11.9	0	---					
Jan 62	14.8	22.9	6.7	0	---	---	---	---	---	---
Feb 62	21.3	29.7	12.8	2	---	---	---	---	---	---
Mrz 62	21.1	29.9	12.4	0	---	---	---	---	----	---
Apr 62	21.6	28.5	14.7	123.5	---	---	---	---	15.5	---
Mai 62	25.1	31.7	17.6	3	---	---	---	---	---	---
Jun 62	25.5	31.7	19.3	84.5	---	27	35.8	18.1	54.9	215.7
Jul 62	25	31.1	18.8	13.5	---	25.6	34.5	16.8	10	211.7
Aug 62	25.4	32.4	18.5	29.4	---	25.8	34.8	16.8	31.4	218.3
Sep 62	24.1	29.5	18.6	49	---	25.4	32.7	18	26.4	118.7
Okt 62	22.4	27.5	17.4	101.8	---	23.4	31.1	15.8	9.7	133.1
Nov 62	18.7	24.8	12.6	58.9	---	18.5	28	8.9	29	95.1
Dez 62	16.4	21.1	11.8	10.5	---	17.7	25.5	9.8	6	106.3
Jan 63	16.5	23.9	9.2	0	---	16.7	26.4	7	0.1	107.7
Feb 63	17.1	25.6	8.7	8	---	17.1	30.1	4.1	2.7	138.8
Mrz 63	22	29.4	14.7	14.5	---	22.1	32.2	12.1	4.9	188.9
Apr 63	26	33.3	18.6	1	---	24.1	33	15.3	0	204.7

month	average temp. [°C]	max. temp. [°C]	min. temp. [°C]	precipitation [mm]	pot. evaporation	average temp. [°C]	max. temp. [°C]	min. temp. [°C]	precipitation [mm]	pot. evaporation
Mai 63	24.4	30.5	18.3	75.2	---	24.9	33.5	16.3	63.5	194.2
Jun 63	25.5	31.4	19.6	169.6	---	26.3	34.4	18.2	114.6	185.1
Jul 63	23.6	28.9	18.4	50.5	---	24.5	31.7	17.3	83	162.8
Aug 63	24.7	31.1	18.4	28	---	24.7	34	15.5	29.7	182.1
Sep 63	23.9	29.4	18.3	59.4	---	24.2	32.3	16	46.4	131
Okt 63	20.2	24.8	15.6	44	---	20.9	27.9	13.9	68.4	89.5
Nov 63	19.2	25.4	12.9	2	---	19	27.5	10.4	12.3	95.4
Dez 63	14	19	9.1	23.5	---	13.4	20.9	5.8	22.8	64
Jan 64	14.7	21	8.3	11	---	13.7	22.5	4.9	16.3	78.4
Feb 64	17.1	24.6	9.6	4.5	---	17.1	27.9	6.3	5.4	121.1
Mrz 64	21.6	29.7	13.5	7	---	18.9	29.6	8.1	3.3	174.1
Apr 64	---	---	---	---	---	25.2	36.5	14	0.1	216.4
Mai 64	25.8	32.5	19	35	---	26.1	35.3	17	44.8	221.7
Jun 64	---	---	---	---	---	25.3	34	16.6	28.8	202.7
Jul 64	---	---	---	---	---	25.4	33.6	17.2	28.4	199.8
Aug 64	25.4	31.7	19.2	34.4	---	25.6	34.5	16.7	17.8	207.9
Sep 64	23.9	28.7	19.1	136.5	---	24.5	31.6	17.3	67.9	125.4
Okt 64	19.1	25.2	13	26.5	---	19.6	28	11.3	63.2	122.2
Nov 64	19.1	24.6	13.7	47	---	18.6	26.3	10.8	11	100.3
Dez 64	16	21.8	10.2	10	---	15.5	24.1	6.8	17.6	73.1
Jan 65	15.8	22.4	9.3	3	---	15.7	24.8	6.6	1.3	90.8
Feb 65	17.1	24.4	9.8	14	---	14.7	22.1	7.2	22.1	106.3
Mrz 65	21	29.6	12.3	9.5	---	20.4	31.2	9.6	0.7	186.7
Apr 65	24.5	31.9	17.2	77.5	---	25.3	36.5	14.1	5.3	208
Mai 65	26.4	33.5	19.4	22	---	26.9	35.3	17.5	45.8	213.9
Jun 65	25.8	32	19.6	49	---	26.5	35.1	17.9	37.7	206.5
Jul 65	23.9	29.2	18.6	30	---	24.3	31.8	16.7	31.8	174.7
Aug 65	23.2	28	18.3	109	---	24.1	30.7	17.5	62.2	133.4
Sep 65	24.1	30	18.2	114	---	24.7	32.8	16.6	114	142.8
Okt 65	19.7	25	14.4	14.5	---	19.6	26.9	12.2	7.9	106.1
Nov 65	19.7	26.2	13.3	5	---	19.2	28.8	9.5	4.4	88.6
Dez 65	17.5	23.3	11.6	10	---	16.7	24.1	9.3	17.2	67.4
Jan 66	13.1	17.9	8.2	26.5	---	14	22.1	5.9	35.4	83.6
Feb 66	16.4	23	9.8	48	---	16.2	23.8	8.6	40.5	93.9
Mrz 66	18.7	24.7	12.8	15.5	---	18.8	26.8	10.8	15.8	121.3
Apr 66	23.9	30.7	17	25	---	21.6	31.4	11.9	7.9	191.8
Mai 66	25.1	32.2	18.1	67.5	---	24.8	35.2	14.3	41.2	208
Jun 66	24	29.2	18.8	314	---	25.1	31.7	18.5	231	285.6
Jul 66	24.5	29.6	19.3	65	---	24.9	32.3	17.5	36.5	168.7
Aug 66	24.6	30	19.1	98	---	24.7	32.1	17.3	61.3	152.8
Sep 66	22.9	29	16.8	43.5	---	23.6	32.1	15.1	35.3	145.8
Okt 66	19.1	24.4	13.9	198	---	19.7	26.4	13	159.1	165
Nov 66	16.4	22.1	10.7	20	---	16.4	24.4	8.3	5.3	99.4
Dez 66	14.4	21.5	7.3	0	---	14.2	24.7	3.7	0.4	76.6
Jan 67	14.1	20.4	7.8	34.5	---	14.1	24.2	3.9	28	74.1
Feb 67	16.2	23.5	8.9	16	---	17.5	29	6	9.7	99.7
Mrz 67	20.2	27.8	12.6	38	---	20.1	30.3	9.9	27.6	148.4
Apr 67	24.6	32	17.3	10	---	25	35.6	14.3	4.7	187.3
Mai 67	25.5	32.6	18.4	57.5	---	25.8	35.7	16	52.5	202.7
Jun 67	25.5	31.5	19.5	38	---	26.3	34.6	18.1	30	188.6
Jul 67	24.8	30.9	18.7	12.5	---	25	34	16	39.6	198.3
Aug 67	24	29.3	18.7	227	---	24.6	32.2	17	103.1	149.9
Sep 67	21.2	25.6	16.9	347	---	22	27.6	16.3	212.7	109.7
Okt 67	18.4	23.1	13.8	61.5	---	19	25.9	12	95.1	67
Nov 67	17.8	23.2	12.3	44	---	18	25.5	10.4	37.4	117.8
Dez 67	16.4	23	9.9	3	---	16.8	26.7	6.8	0	63.4
Jan 68	16	21.2	10.9	6	---	16.8	24.4	9.2	4.4	56.7
Feb 68	15.7	21.8	9.6	22.5	---	15.8	23.7	7.9	25.9	101.9
Mrz 68	17.7	24.9	10.4	49.5	---	17.2	27.3	7.1	41.8	104
Apr 68	23.6	30.6	16.6	45.1	---	22	31.8	12.2	10.8	154.9
Mai 68	25	31.7	18.4	46.7	---	25.2	34.4	16	43.3	186.3

month	average temp. [°C]	max. temp. [°C]	min. temp. [°C]	precipitation [mm]	pot. evaporation	average temp. [°C]	max. temp. [°C]	min. temp. [°C]	precipitation [mm]	pot. evaporation
Jun 68	25.1	31.4	18.8	149.9	---	25	33.7	16.3	64.8	201.5
Jul 68	23.4	28.2	18.5	80.4	---	22.5	29.7	15.2	47	190.1
Aug 68	23.3	28.4	18.2	76.6	---	23.4	30.9	15.9	72.4	129.3
Sep 68	21.9	26	17.9	182.3	---	22.7	29.9	15.4	62.4	146.9
Okt 68	21.3	26.2	16.3	27.5	---	22.7	30.6	14.9	13.5	93.3
Nov 68	---	---	---	---	---	19	27.5	10.4	4.5	81.7
Dez 68	15.7	21.8	9.5	10.2	---	15.9	24.9	6.8	12.5	62.5
Jan 69	16.5	23	10	24.9	---	16.5	25.4	7.6	27.1	81.2
Feb 69	18.8	25.6	12.1	0	---	18.7	27.7	9.7	0.8	98.9
Mrz 69	19	26.2	11.8	0	---	19.7	29.9	9.6	0	133.8
Apr 69	24.7	32	17.4	49.8	---	25.3	35.7	14.8	7.9	179.7
Mai 69	25.8	32.7	18.8	11.3	---	---	---	---	---	---
Jun 69	26.9	33.4	20.4	74.6	---	27.5	36.9	18	32.5	210.5
Jul 69	24.9	30.4	19.5	100.1	---	26	34.5	17.6	43.3	177.9
Aug 69	24	28.9	19	273.9	---	24.5	32.2	16.8	218.6	146.6
Sep 69	---	---	---	---	---	---	---	---	---	---
Okt 69	21.7	26.7	16.7	24.3	---	22.7	30.9	14.5	11	116
Nov 69	17.2	22.7	11.8	16.5	---	18.4	25.9	10.9	6	76.8
Dez 69	16.3	22.2	10.5	3.5	---	16.5	25.2	7.8	0.6	58.9
Jan 70	15	21.9	8.1	0	---	14.6	23.4	5.9	0.1	79.6
Feb 70	15.4	21.8	8.9	51	---	13.7	23.3	4.1	5.6	70.8
Mrz 70	20.2	28.1	12.3	0	---	17.8	30.3	5.4	0	148.1
Apr 70	25.5	34	16.9	1	---	22.6	36.9	8.4	0	206.4
Mai 70	23.8	30.7	17	84.8	---	22.9	33.3	12.5	19.5	174.2
Jun 70	23.6	29.1	18.2	170	---	22.4	31.9	12.9	84.2	160.1
Jul 70	23.2	28.4	18.1	75.2	---	22.6	31.7	13.5	31.6	162.4
Aug 70	24	29.3	18.7	131.3	---	23	32.9	13.1	65.6	145.8
Sep 70	22.2	26.3	18	170.4	---	21.5	29.1	13.9	84.8	136.4
Okt 70	21.3	26.9	15.8	3	---	22.1	30.5	13.7	0	119.1
Nov 70	15.6	23	8.2	0	---	19.2	26.6	11.7	0	62.7
Dez 70	18	24.4	11.7	6.5	---	19.3	27.2	11.5	2.5	63.6
Jan 71	17.8	25.3	10.3	1	---	17.2	30.1	4.3	0	79.1
Feb 71	18.3	27.3	9.4	0	---	21.3	30.6	12	0	158.8
Mrz 71	21.5	30.2	12.7	3.7	---	22.7	35.1	10.4	0	192
Apr 71	22.9	31.1	14.8	2.3	---	25.9	38.8	13	0	167.3
Mai 71	25.1	32.2	18	118	---	23.4	35.7	11.1	46.5	167
Jun 71	---	---	---	---	---	26.6	32	21.1	80	170.7
Jul 71	23.2	28.3	18.1	27.3	---	23	32.4	13.6	6	113.4
Aug 71	22.3	27.1	17.5	133.2	---	21.5	29.4	13.6	140.6	173.7
Sep 71	22.6	27.2	18	121.9	---	27.5	33.5	21.5	102.8	107.8
Okt 71	21.2	25.6	16.7	66.5	---	20.2	27.5	12.8	34.5	118.9
Nov 71	18.3	23.8	12.7	32.3	---	20.2	28.2	12.2	1.8	139.4
Dez 71	18.5	24.4	12.7	16.3	---	19.9	27.1	12.8	25.7	157.4
Jan 72	16.7	22.9	10.6	13.2	---	17.7	26.4	9	8.6	130.6
Feb 72	17.6	24.8	10.5	0	---	19.9	27.3	12.5	0	188
Mrz 72	22.1	29.5	14.6	20.9	---	23.7	32.7	14.8	11.5	137.1
Apr 72	25.8	33.4	18.1	1.2	---	24	36.5	11.6	8.5	186.1
Mai 72	25.6	31.9	19.4	40.9	---	28	35.3	20.8	51	237.9
Jun 72	24.4	29.7	19	107.2	---	27.1	34.3	19.9	69.5	237.7
Jul 72	22.9	27.7	18.2	234	---	26.3	33.4	19.1	100.5	291.1
Aug 72	22.9	27.8	17.9	67.5	---	23.6	30.8	16.4	16.8	141.7
Sep 72	23.7	29.4	18.1	20.2	---	22.9	33	12.9	26.1	100.2
Okt 72	23	28.7	17.3	33	---	21.2	30.4	12	33	126.2
Nov 72	19.7	24.9	14.5	2.5	---	22.5	27.2	17.8	12.9	97.4
Dez 72	16.9	23.8	10.1	0	---	21.6	27.4	15.8	0	110.3
Jan 73	15.3	22.6	8	2	---	16.3	24.7	7.8	0.1	152.4
Feb 73	16.8	24.1	9.5	5.8	---	19.2	26.2	12.2	4.8	189.4
Mrz 73	23.7	32.8	14.5	0	---	21.9	31.2	12.6	4.5	218.3
Apr 73	23.7	32.1	15.3	22	---	24.1	34.7	13.5	42	263.3
Mai 73	25.6	32.6	18.7	24.8	---	29.6	37.5	21.8	10.4	213.2
Jun 73	24.4	29.8	19.1	235.9	---	26.5	32.1	21	141.8	149.5

month	average temp. [°C]	max. temp. [°C]	min. temp. [°C]	precipita-tion [mm]	pot. eva-poration	average temp. [°C]	max. temp. [°C]	min. temp. [°C]	precipi-tation [mm]	pot. eva-poration
Jul 73	23.9	28.9	19	131.1	---	26.8	32.4	21.1	64.4	138.5
Aug 73	22	26.3	17.7	162.3	---	25.7	28.3	23.2	143.3	133.4
Sep 73	23.7	28.7	18.6	118	---	22.5	30.8	14.2	36	130.8
Okt 73	20.8	25.7	15.9	59.1	---	19.2	26.4	12	7.7	182.5
Nov 73	19.9	26	13.9	15	---	19.5	28.2	10.9	0.2	130.6
Dez 73	15.8	23.1	8.4	13.9	---	16	25	7	0	161.9
Jan 74	18.1	25	11.1	0	---	19.9	27.5	12.3	0	145
Feb 74	17.2	25.5	8.8	4.5	---	17	25.9	8.2	0	159.9
Mrz 74	22.4	30.8	14	2.8	---	22.8	33.4	12.2	35.3	150.2
Apr 74	24	31.1	16.8	48.2	---	29	37.7	20.3	10.8	196.8
Mai 74	26.1	33.3	18.9	2.8	---	31.7	39.8	23.5	3.2	209.5
Jun 74	24	29.7	18.2	115.1	---	29.3	36.1	22.6	62	223.2
Jul 74	22.5	27.7	17.4	77.2	---	22.8	32.6	13	54.9	173.6
Aug 74	24.3	29.9	18.7	47.4	---	22.3	30.8	13.7	16	187.8
Sep 74	22	26.6	17.3	257.8	---	26.7	32.6	20.7	130.6	143
Okt 74	19	24	14	31.9	---	21	30.1	11.9	17.6	145.1
Nov 74	17.4	23	11.8	3.6	---	18.8	26.3	11.4	0.9	132.1
Dez 74	15.8	20.8	10.9	19.6	---	18.5	26.4	10.6	1.9	158.4
Jan 75	15.2	21.8	8.6	40.4	---	18.9	27.9	9.9	30.1	167.8
Feb 75	18.2	25.9	10.6	0	---	21.1	31.6	10.5	0	124.1
Mrz 75	22.6	31.3	13.9	3.3	---	25.3	38.5	12.2	0	136.3
Apr 75	25.4	33.8	17	3.4	---	26.4	39.8	12.9	0	154.3
Mai 75	26.1	32.9	19.2	62.9	---	25.8	37.4	14.3	45.2	218.5
Jun 75	24.5	30	18.9	107.5	---	25.1	36.2	14.1	51.7	235
Jul 75	23	28.3	17.7	141.2	---	23.6	33.7	13.5	86.9	158
Aug 75	23	27.9	18.2	95.5	---	24.5	34.5	14.5	33.1	117.6
Sep 75	20.6	25.4	15.8	184.5	---	22	30.8	13.2	47.8	153.3
Okt 75	20.2	25.4	15	67.8	---	20.9	29.2	12.5	13.2	211.7
Nov 75	17.2	23.5	10.8	3.2	---	21.4	30	12.8	0.2	172.4
Dez 75	15.8	22.2	9.5	13	---	19.8	28.5	11.2	0.7	180.4
Jan 76	13.6	20.3	7	5	---	18.1	25.4	10.8	0.3	144.5
Feb 76	17.3	25.9	8.7	0	---	21	29.7	12.3	0	166.9
Mrz 76	22.5	30	14.9	41.6	---	21.4	30.6	12.3	10.1	192.5
Apr 76	23.4	30.5	16.3	14.7	---	22.9	34.1	11.7	20.9	162.4
Mai 76	24.4	31.3	17.4	38.7	---	24.4	33.4	15.4	38	310.8
Jun 76	24.5	30.2	18.8	149.1	---	23.2	31.7	14.8	38.9	226.3
Jul 76	22	25.9	18	226.5	---	19.8	26.6	13	187.1	138.6
Aug 76	22.5	27.6	17.5	65.2	---	21	27.9	14.2	29	126.4
Sep 76	22.7	27.4	17.9	64.4	---	21.5	29	14.1	74.9	123.1
Okt 76	19.3	24.3	14.4	30.5	---	19.7	26.1	13.3	28.2	125
Nov 76	14.8	18.8	10.7	32.8	---	16.8	22.2	11.5	37.8	114.6
Dez 76	13.5	18.2	8.8	12	---	14.4	20	8.7	8.2	58.3
Jan 77	15	20.6	9.4	8.9	---	15.5	22.9	8.1	3.4	79.5
Feb 77	16.6	23.4	9.7	0	---	18.6	26.6	10.6	1.2	111.6
Mrz 77	21.6	30.3	12.9	2.3	---	21.7	32.1	11.4	5.4	175.2
Apr 77	22	28.8	15.2	6.3	---	21.8	30.4	13.1	3.2	247.1
Mai 77	24.6	31.1	18.2	94.7	---	24.3	33.2	15.3	53.6	177.1
Jun 77	24.3	30.1	18.5	119.5	---	24.1	31.4	16.9	23	228.9
Jul 77	24.2	30.2	18.2	14.5	---	23.1	31.3	14.9	18	179.4
Aug 77	24.9	31.4	18.5	113.4	---	24.2	32.8	15.6	69.5	195.2
Sep 77	23.3	28.4	18.1	122.5	---	23.3	30.5	16.1	106.5	158.3
Okt 77	---	---	---	---	---	20.8	27.4	14.2	52.9	111.9
Nov 77	18.3	24.2	12.3	10.5	---	18.4	26.7	10	7.4	104.1
Dez 77	17.1	24.4	9.8	1	---	16.4	25.3	7.5	1	92.9
Jan 78	16	23	9	0	---	15.5	25	6	0	133.2
Feb 78	16.3	22.7	9.8	2.4	---	16.8	25.7	8	27.3	114.6
Mrz 78	19.3	27.1	11.5	56.2	---	19.2	29.3	9	21.2	161.5
Apr 78	24.8	33.2	16.4	4.5	---	23.4	33.7	13.1	9.7	205.2
Mai 78	27.3	34.8	19.8	73.4	---	25.9	35.2	16.5	27	224.4
Jun 78	24.8	30.6	19.1	111.5	---	24.5	31.7	17.3	45.9	190.7
Jul 78	24.6	30.8	18.4	115.9	---	23.7	31.6	15.8	52.3	204.1

month	average temp. [°C]	max. temp. [°C]	min. temp. [°C]	precipita-tion [mm]	pot. eva-poration	average temp. [°C]	max. temp. [°C]	min. temp. [°C]	precipi-tation [mm]	pot. eva-poration
Aug 78	23.7	29.2	18.3	44.5	---	23.1	30.2	16	51	165.8
Sep 78	22.5	27.6	17.5	308.2	---	22.7	28.7	16.6	104.1	136
Okt 78	19	22.8	15.2	84.9	---	18.7	24.8	12.7	35.8	90.5
Nov 78	19.8	24.4	15.1	8.4	---	19.8	25.9	13.6	13.4	90
Dez 78	16.9	22.7	11.1	0	---	19	27.9	10.2	6	129
Jan 79	13.5	20.2	6.7	0	---	14.9	24.2	5.5	0	114.9
Feb 79	17.3	24.4	10.2	13.5	---	16.8	26.7	6.9	7	113.1
Mrz 79	20.7	28.2	13.3	14.1	---	19.6	29.1	10	2.4	201
Apr 79	24.1	31.3	16.9	71.2	---	23.9	32.8	15	47.4	185.8
Mai 79	24.3	31.5	17.2	0	---	24.3	33	15.6	0	212.6
Jun 79	24.4	30.2	18.5	62.3	---	22.6	31.1	14.1	22.9	169.9
Jul 79	25.9	32.3	19.4	31.8	---	24.9	32.3	17.5	39.8	201.4
Aug 79	23.3	28.5	18.2	97.1	---	22	29	15.1	86.6	169.3
Sep 79	21.5	26.7	16.3	70.3	---	19.5	26.9	12.2	17.9	138.5
Okt 79	22	30.5	13.5	8	---	20.6	31.5	9.8	2	164.2
Nov 79	16.4	22.2	10.7	19	---	16.1	23.4	8.8	9	92.9
Dez 79	15.2	20	10.4	113.9	---	14.5	19.8	9.2	149.1	70.3
Jan 80	14.3	21.9	6.7	24	---	---	---	---	---	---
Feb 80	16.5	24.1	8.8	22.9	---	---	---	---	---	---
Mrz 80	21.7	30.8	12.5	2	---	21.1	32.9	9.3	0	173.5
Apr 80	21.9	29.3	14.5	24.5	---	21.4	30.8	12	7.3	168.3
Mai 80	27	34.5	19.5	19.5	---	26.3	35.5	17.2	28.6	221.1
Jun 80	26.2	32.8	19.7	4	---	24.7	32.9	16.5	0	202.6
Jul 80	26.3	32.9	19.7	75.6	---	24.9	33.4	16.5	6.5	226.4
Aug 80	25.3	31.4	19.3	40.5	---	---	---	---	---	---
Sep 80	23.3	28.3	18.3	163.1	---	---	---	---	---	---
Okt 80	20	25.3	14.8	44.2	---	20.1	27.4	12.8	120.5	117.4
Nov 80	15.6	21.2	10	3.9	---	15.3	21.9	8.7	6.7	72
Dez 80	15.1	21.1	9.2	24.6	---	16.1	24.2	8	24.7	70.3
Jan 81	13.6	18.9	8.3	56.6	---	12.4	18.1	6.8	57.2	67
Feb 81	16.6	22.3	10.8	11.5	---	---	---	---	---	---
Mrz 81	20.4	27.8	13	8.7	---	20.3	29.9	10.8	4.9	154.7
Apr 81	23.1	29.5	16.7	130.4	---	---	---	---	---	---
Mai 81	24	30.4	17.7	113.1	---	24.2	32.5	16	79.3	173.8
Jun 81	23.8	28.6	19	315.6	---	---	---	---	---	---
Jul 81	23.4	28.5	18.3	92.7	---	22.8	29.3	16.4	141.5	156.7
Aug 81	24.1	30.1	18	64.8	---	21.2	28.9	13.6	33.5	182.2
Sep 81	22.4	27.6	17.3	74.5	---	---	---	---	---	---
Okt 81	21.4	26.8	16	32.6	---	21.1	27.4	14.8	33.6	114.5
Nov 81	18.2	26.1	10.4	1.5	---	16.2	25.1	7.2	0	102
Dez 81	17	22.8	11.2	51.6	---	14.7	21.2	8.1	22.9	83.8
Jan 82	17.2	25.3	9	4.3	---	---	---	---	---	---
Feb 82	17.8	25.1	10.4	5.8	---	17.1	26.3	7.9	8.9	110.9
Mrz 82	22.2	30.7	13.7	9.8	---	22.7	34	11.4	13.4	174.1
Apr 82	25.6	33.4	17.8	41.5	---	24.5	34.4	14.5	30.5	191
Mai 82	24.2	30	18.4	118.4	---	25	32.7	17.2	18.4	211.7
Jun 82	26.6	33.7	19.6	12	---	25.9	35.6	16.2	6.2	213.3
Jul 82	24.8	30.8	18.9	7.2	---	23.7	31.8	15.5	15.7	185.4
Aug 82	24.9	31.2	18.6	63.8	---	23.8	32.2	15.5	18.2	187
Sep 82	23.4	29.2	17.6	68.8	---	22.5	30	15.1	56.5	149.3
Okt 82	20.5	25.6	15.3	92.5	---	20.5	27.8	13.3	78.7	120.1
Nov 82	17.7	23.5	11.8	18.8	---	15.1	21.2	8.9	19	86.9
Dez 82	15.2	21.2	9.2	31.9	---	---	---	---	---	---
Jan 83	14.3	19.7	8.8	17.1	---	14	21.3	6.6	22.8	66.1
Feb 83	17.7	26.4	9	1	---	16	25	7	12	110.6
Mrz 83	21	30.1	11.9	0	---	18.9	29.6	8.2	0	180.1
Apr 83	23.6	33	14.3	0	---	21.6	32.9	10.3	0	206.9
Mai 83	26.6	34.2	19	75.5	---	23	31.3	14.7	40.6	210.8
Jun 83	26.6	33.7	19.4	10	---	24.6	32.9	16.4	43.7	179.7
Jul 83	23.1	27.7	18.5	264	---	21.3	25.6	17	142.6	117.3
Aug 83	23.7	29.2	18.3	47.2	---	20.7	25.3	16	45.7	114

month	average temp. [°C]	max. temp. [°C]	min. temp. [°C]	precipita-tion [mm]	pot. eva-poration	average temp. [°C]	max. temp. [°C]	min. temp. [°C]	precipi-tation [mm]	pot. eva-poration
Sep 83	22.6	27.5	17.7	112.4	---	20.4	25.4	15.4	65.8	109.6
Okt 83	21.2	27	15.4	44.2	---	18.3	24.4	12.3	39.8	113.7
Nov 83	19.8	26.7	12.8	23.2	---	17.8	25.5	10.2	11.8	117.7
Dez 83	16.9	24.8	9	1	---	15.5	22.9	8	0	95.9
Jan 84	14.3	19.8	8.8	51.3	---	16.3	24.9	7.8	41.5	69.1
Feb 84	15.9	22.6	9.2	12.7	---	15.4	23.9	6.9	11.4	104.2
Mrz 84	20.9	29.4	12.4	0	---	20.3	31.1	9.6	20.3	176.6
Apr 84	25.7	35	16.4	0	---	21.6	32.2	10.9	0	256.7
Mai 84	24.5	31.7	17.4	138	---	23.4	32.8	14.1	73.2	202.8
Jun 84	24.4	30.6	18.2	64.8	---	23	29.9	16.1	54.2	174.7
Jul 84	22	26.5	17.4	182.7	---	20.1	25.5	14.7	118.7	124.6
Aug 84	23.3	28.9	17.7	59	---	22.2	28.9	15.4	78.2	160.2
Sep 84	20.4	24	16.7	205.5	---	19.4	23.7	15.1	98.6	90
Okt 84	21.9	27.4	16.4	3.8	---	20.4	26.5	14.4	0	133.5
Nov 84	17.5	24	11	9.9	---	16.3	23.9	8.8	11.8	108.6
Dez 84	---	---	---	---	---	14.5	20.7	8.4	32.2	76.6
Jan 85						12.7	21.3	4	10.3	95.3
Feb 85						17.2	26.7	7.6	3	116.1
Mrz 85						21.2	30.5	11.8	0	174.5
Apr 85						20.2	27.4	13	63.8	159.7
Mai 85						23.7	31.6	15.8	50.4	189.2
Jun 85						22.5	28.7	16.4	62.9	155.7
Jul 85						21.3	27	15.6	121.1	150.9
Aug 85						22.4	29.1	15.7	9.5	170.7
Sep 85						21.2	27.2	15.3	32.5	137.1
Okt 85						18.6	25.1	12.1	11	131.7
Nov 85						17.1	23.6	10.7	6.5	110.5
Dez 85						14.3	21.3	7.3	11.1	78.2
Jan 86						12.8	21.7	3.9	0	93.2
Feb 86						16.9	27.8	5.9	0	139.4
Mrz 86						20.1	30.5	9.6	0	185.5
Apr 86						23.1	32.3	13.9	56.2	184.6
Mai 86						22.6	29.7	15.5	6.5	174.6
Jun 86						22.4	28.4	16.4	120.5	149.8
Jul 86						21.7	27.8	15.7	107.7	140.3
Aug 86						23.4	31.1	15.7	0	179.8
Sep 86						21.2	27.5	14.9	39.8	148.7
Okt 86						---	---	---	---	---
Nov 86						---	---	---	---	---
Dez 86						---	---	---	---	---
Jan 87	---	---	---	---	---	12.8	21.5	4.2	13.2	89.1
Feb 87	---	---	---	---	---	15.2	23.6	6.8	10.5	106.5
Mrz 87	19.6	27.4	11.7	6.3	---	19.2	28.7	9.7	7	155.5
Apr 87	20.5	27.5	13.5	35.5	---	19.5	27.1	11.9	12.6	132.7
Mai 87	24.8	31.4	18.1	56.2	---	22	29.6	14.4	71.7	170.1
Jun 87	24.6	30.3	19	146.2	---	24.1	31.5	16.7	51.2	170.4
Jul 87	22.8	26.9	18.6	167.2	---	22.4	27.4	17.4	116	149.3
Aug 87	24.4	30.1	18.7	10	---	23.4	30.1	16.7	5.5	169.3
Sep 87	24.6	31.3	17.9	81.8	---	23.4	30.7	16.2	70.5	156.5
Okt 87	20.4	27.2	13.6	7.3	---	17.7	25.3	10.1	0	124.4
Nov 87	18.3	24.7	11.8	9	---	16.6	23.4	9.9	36.9	96.6
Dez 87	18.1	24.5	11.6	0	---	15.1	22.1	8.1	2	87
Jan 88	15.2	22	8.4	5	---	13.9	21.7	6.1	16.8	83.1
Feb 88	17.7	25.2	10.1	0	---	15.5	22.8	8.2	2.8	104.6
Mrz 88	19.6	26.9	12.3	52.5	---	19.3	28.1	10.5	22.3	150.5
Apr 88	24.1	31.8	16.4	26	---	20.9	28.7	13.2	57.6	158.6
Mai 88	25.5	32.3	18.6	102	---	22.6	29.5	15.8	6.5	180.9
Jun 88	24.7	30.4	19	128.5	---	23.8	30.8	16.7	77.8	176.7
Jul 88	23.7	28.6	18.8	177.8	---	23	28.9	17.1	71.5	163.6
Aug 88	23.2	27.9	18.4	144.3	---	22.8	29.7	16	137.6	150.8
Sep 88	22.7	28.1	17.2	49	---	20.3	27.4	13.1	65	142.5

month	average temp. [°C]	max. temp. [°C]	min. temp. [°C]	precipitation [mm]	pot. evaporation	average temp. [°C]	max. temp. [°C]	min. temp. [°C]	precipitation [mm]	pot. evaporation
Okt 88	21.1	26.6	15.6	53.3	---	18.9	25.4	12.3	31.1	132.2
Nov 88	20.9	29.4	12.4	0	---	19.1	29.2	9.1	3.5	112.8
Dez 88	17.1	23.5	10.7	0	---	16	24.1	7.9	0.1	71.4
Jan 89	19.4	26	12.8	3.2	---	17.7	25.6	9.7	1.5	80.8
Feb 89	18.5	26	11.1	17.7	---	16.8	25.7	7.9	8.5	90.2
Mrz 89	21	30.8	11.2	0	---	18.6	31.1	6.1	0	186.6
Apr 89	23.7	31.9	15.4	37.5	---	22.2	33.2	11.2	185	164.8
Mai 89	26.6	33.9	19.2	6.7	---	25	34.7	15.4	16.4	224.4
Jun 89	26.8	33.9	19.8	56.5	---	25.1	33.5	16.7	58.8	219.6
Jul 89	25.3	32	18.7	26	---	23.6	31.1	16.1	28	186.9
Aug 89	24	29.4	18.7	159.1	---	23	29.2	16.8	109.5	152.9
Sep 89	22.6	28	17.1	66.7	---	21	27.6	14.4	43.5	123.2
Okt 89	20.5	27.4	13.6	21	---	19.2	28.7	9.8	3.2	101.6
Nov 89	20.1	26.5	13.6	7.5	---	17.5	25.6	9.5	9	66.4
Dez 89	14.6	20.6	8.6	32.7	---	12.5	20.1	4.8	48.1	49.3
Jan 90	17.4	23.8	11	19	---	16.1	24.3	8	5.8	74.1
Feb 90	18.9	27	10.7	10.5	---	17.1	26.7	7.5	17.9	100.7
Mrz 90	21.4	29.2	13.6	9	---	19.5	28.5	10.6	0	153.3
Apr 90	24.5	31.8	17.1	0	---	22.5	31.3	13.6	0	163.8
Mai 90	26.5	33.8	19.2	47.1	---	24.3	33	15.5	57.5	177.4
Jun 90	25.8	32	19.7	81.7	---	24.4	31.2	17.6	54.5	146.3
Jul 90	24.1	29.4	18.8	43.4	---	23.3	29.2	17.4	32.8	137
Aug 90	23.3	28	18.5	219.5	---	22.5	28.1	16.9	89	137.9
Sep 90	22.5	27	18	200.9	---	22.1	27.6	16.6	93.9	80.3
Okt 90	20.3	25.5	15.1	114.5	---	19.2	24.8	13.5	106	56
Nov 90	18.6	24.9	12.3	27.4	---	17.8	25.2	10.5	11	55.6
Dez 90	15.4	22.8	8	0	---	14.2	24.1	4.4	3.5	57.7
Jan 91						17.3	24.9	9.8	3.5	76.4
Feb 91						17.2	25.4	8.9	3.7	86.4
Mrz 91						22	34.3	9.7	0	173.9
Apr 91						25.3	35.7	14.9	0	143.6
Mai 91						26.7	35	18.3	38.7	219.8
Jun 91						25.2	31.7	18.6	34.5	152.3
Jul 91						21.5	25.9	17	242.2	90.1
Aug 91						22.8	29.5	16	50.2	143.7
Sep 91						21	25.9	16.1	93.3	81
Okt 91						19	24.7	13.3	38.1	75.6
Nov 91						16	23.8	9.5	4.5	56.9
Dez 91						16.6	22.9	10.3	14	57.4
Jan 92						---	---	---	---	---
Feb 92						16.5	23.7	9.3	5.8	91.5
Mrz 92						21.1	30.2	12	9.4	138.8
Apr 92						21.3	30	12.6	45.7	137
Mai 92						22.7	30.3	15.1	115.3	158.6
Jun 92						24.4	33.3	15.5	36	194.6
Jul 92						24	31.2	16.8	63.7	145.5
Aug 92						23.7	31.5	15.9	35.7	184.9
Sep 92						22.9	29.9	15.9	17.5	124.8
Okt 92						---	---	---	---	---
Nov 92						---	---	---	---	---
Dez 92						---	---	---	---	---
Jan 93						22.7	32.3	13.1	0	115.2
Feb 93						17.1	24.2	9.9	0	145
Mrz 93						17.7	24.1	11.4	0	140.2
Apr 93						---	---	---	---	---
Mai 93						25.9	38.7	13.1	74.3	201
Jun 93						25.9	38.1	13.6	168	---
Jul 93						---	---	---	---	---
Aug 93						---	---	---	---	---
Sep 93						---	---	---	---	---
Okt 93						---	---	---	---	---

month		average temp. [°C]	max. temp. [°C]	min. temp. [°C]	precipitation [mm]	pot. evaporation
Dez 93		---	---	---	---	---
Jan 94		18.9	32.1	5.7	0	---
Feb 94		19	32	5.9	0	---
Mrz 94		18.4	24.9	11.8	0	---
Apr 94		22.8	32.2	13.4	20	---
Mai 94		24.6	34.2	14.9	67	---
Jun 94		19.4	25.9	12.9	3.4	---
Jul 94		26.5	34.5	18.6	0	---
Aug 94		23.9	30.4	17.3	116	---
Sep 94		24.3	30.6	17.9	0	---
Okt 94		16.5	19.8	13.2	0	---
Nov 94		24.9	28.6	21.2	0	---
Dez 94		---	---	---	---	---

App.No.3.: Meteorological data from Media Luna and El Huizachal station

		Media Luna								
month	average temp. [°C]	max. temp. [°C]	min. temp. [°C]	precipitation [mm]	pot. evaporation					
Jan 79	---	---	---	---	---					
Feb 79	---	---	---	---	---					
Mrz 79	---	---	---	---	---					
Apr 79	---	---	---	---	---					
Mai 79	---	---	---	---	---					
Jun 79	---	---	---	---	---					
Jul 79	26.9	33.8	20	29.8	210.1					
Aug 79	24.3	29.9	18.8	65.8	139.6					
Sep 79	22.8	28.3	17.3	52.1	129.8					
Okt 79	---	---	---	---	---					
Nov 79	17.1	23.1	11	14.7	81.4			**El Huizachal**		
Dez 79	15.9	20.8	10.9	89	73.3	average temp. [°C]	max. temp. [°C]	min. temp. [°C]	precipitation [mm]	pot. evaporation
Jan 80	16.9	23.5	10.3	20.5	71.9	---	---	---	---	---
Feb 80	16.7	24.9	8.4	16	101.2	---	---	---	---	---
Mrz 80	22.5	32.2	12.8	0	190.8	---	---	---	---	---
Apr 80	23.1	31.6	14.6	18	181.2	---	---	---	---	---
Mai 80	27.5	35.1	19.9	30.5	206.4	---	---	---	---	---
Jun 80	26.6	33.6	19.6	3	211.2	---	---	---	---	---
Jul 80	26.8	33.9	19.6	16.5	222	---	---	---	---	---
Aug 80	26.1	32.7	19.5	50	190.5	---	---	---	---	---
Sep 80	24.3	30.1	18.5	131	130.4	---	---	---	---	---
Okt 80	20.9	26.6	15.3	33.2	107.3	---	---	---	---	---
Nov 80	16.5	22.7	10.3	3.4	70.5	21	30.5	11.5	3	76
Dez 80	16.4	23	9.9	18.3	70.3	21.2	30.8	11.6	15.5	63.8
Jan 81	13.8	19.8	7.7	53.9	62.9	---	---	---	---	---
Feb 81	17.2	23.4	11	11.2	91.5	---	---	---	---	---
Mrz 81	21.2	28.9	13.4	8.6	159.8	---	---	---	---	---
Apr 81	24.1	31	17.3	112.9	163	---	---	---	---	---
Mai 81	25.5	32.6	18.4	199.6	184.2	25.4	33.2	17.6	126	190.3
Jun 81	25	30.4	19.7	234.3	143.4	25	31.3	18.7	255.5	184.2
Jul 81	24.6	30.4	18.8	91.2	161.5	24.2	30.6	17.9	60	168.7
Aug 81	24.9	31.5	18.3	48.6	168.6	24.3	31.2	17.4	26.5	177.3
Sep 81	23.7	29.7	17.8	82.4	138.2	23.1	30.3	15.9	60.5	117.8
Okt 81	22.7	28.1	17.3	33.4	108.8	22.4	29.6	15.1	22	118
Nov 81	18.8	28	9.6	0	103.3	20.6	28.5	12.8	6.5	159.6

month	average temp. [°C]	max. temp. [°C]	min. temp. [°C]	precipitation [mm]	pot. evaporation	average temp. [°C]	max. temp. [°C]	min. temp. [°C]	precipitation [mm]	pot. evaporation
Dez 81	17.2	24.1	10.4	38.8	74.8	17.5	24.9	10.1	34	97.8
Jan 82	---	---	---	---	---	17.6	27.6	7.7	1.3	95.9
Feb 82	---	---	---	---	---	19	27.3	10.7	7.2	106.4
Mrz 82	---	---	---	---	---	21.2	31.3	11.1	50	174.2
Apr 82	---	---	---	---	---	24.8	33.2	16.4	6.2	159.5
Mai 82	25.4	31.4	19.4	80.8	152.5	25.1	32.1	18.1	52.4	102.2
Jun 82	27.4	35.3	19.6	4	220.5	27	35	18.9	0	207.1
Jul 82	25.8	32.5	19.1	11.9	197	24.8	31.4	18.3	8.5	151.4
Aug 82	25.6	32.8	18.5	13.4	190.4	25.1	32.2	18.1	15	194.1
Sep 82	24.4	30.8	17.9	80	147	23.6	30	17.1	38.5	187.1
Okt 82	21.3	27	15.5	65.5	117.3	21.4	27.9	15	43.5	115.7
Nov 82	18.7	25.4	12	28.2	93	18.3	25.4	11.2	16.5	91.5
Dez 82	15.3	22.2	8.4	31.3	75.4	18	27	9.1	18.5	71.5
Jan 83	14.9	21.2	8.6	15.9	81	16.1	22.5	9.8	2	58.3
Feb 83	18.1	27.2	9.1	2.7	139	18.2	28.1	8.3	7	61.2
Mrz 83	21.2	31.3	11.1	0	220.3	18.5	29.1	8	0	139.7
Apr 83	23.8	34	13.6	0	237.6	21.2	32.3	10	0	149
Mai 83	27	35.2	18.8	61.3	207.4	26.1	34.7	17.5	60	202.4
Jun 83	27.2	34.7	19.7	6.2	215.7	26.9	34.8	18.9	0	218.7
Jul 83	24.1	29.3	19	231.9	144.8	24.2	30.3	18.1	144.5	187.3
Aug 83	24.6	30.8	18.5	34.6	163.2	24.4	30.9	17.9	16.5	176.6
Sep 83	23.5	29	18.1	84.5	118.7	22.7	28.8	16.6	76.5	133
Okt 83	21.7	28	15.5	31.6	118	21.9	29	14.8	29	182.3
Nov 83	20.5	28.2	12.8	27.2	107.9	21.1	29.9	12.4	29	164
Dez 83	17.1	24.7	9.5	0	94.4	18.9	26.7	11.1	0	91.5
Jan 84	15	21.2	8.8	39	72.4	15.5	22.4	8.7	19.5	93.7
Feb 84	16.8	24.5	9.2	9.6	111.7	17.5	25.4	9.5	9	102.2
Mrz 84	21.1	30.4	11.7	0	182.7	22	31.8	12.2	0	151.1
Apr 84	25.6	36.3	14.9	0	246.3	25.7	36	15.3	0	191.5
Mai 84	25	33	17	102.1	200.3	25	32.9	17.1	66.4	139.5
Jun 84	25.5	32.3	18.6	51.3	164.7	24.9	21.9	17.9	19	148.8
Jul 84	22.8	27.7	17.8	145.8	105.4	23.9	29.9	17.9	144.5	159.8
Aug 84	23.9	30.2	17.6	52.9	140.1	---	---	---	---	---
Sep 84	21.3	25.4	17.1	196.7	73.7	21.8	26.6	17	231.1	94
Okt 84	23.1	29.5	16.8	1.6	114.7	22.6	29.6	15.6	0	110.8
Nov 84	18.1	26.1	10.1	0	91.4	18.8	26.4	11.2	27	124.9
Dez 84	18.5	25.5	11.4	11.1	75.2	21.8	28.8	14.7	17	115
Jan 85	14.7	23.4	6.1	6	82.4	16.3	25.6	7	9.5	83.1
Feb 85	18.2	26.6	9.8	1	109.3	18.7	26.1	11.2	73.5	---
Mrz 85	22.5	30.9	14.1	0	169.2	22.8	30.6	14.9	0	83.8
Apr 85	23.2	31	15.3	95.8	149.3	23.6	31.4	15.8	146.8	105.5
Mai 85	25.6	33.7	17.6	56.9	180.4	23.5	28.4	18.6	67	138.4
Jun 85	24.9	31.1	18.7	154	149.3	25.8	32	19.6	186.6	96.9
Jul 85	22.9	28.5	17.4	193	126.9	24	29.9	18	205.2	98
Aug 85	24.7	31.2	18.4	70.3	155.4	26	31.9	20.1	15.5	108.7
Sep 85	24.1	30.7	17.5	29.1	136.1	24.1	31.3	16.8	44.5	105.1
Okt 85	23	30.7	15.3	1.2	129.6	22.8	30.2	15.4	17.6	110.8
Nov 85	21.2	29.5	12.9	12.2	115	21.6	29.5	13.8	17.5	140
Dez 85	16.4	23.3	9.5	6.9	73	17	24.3	9.6	16.5	89.1
Jan 86						16.5	20.1	12.8	0	99
Feb 86						18.3	26.3	10.3	0	107
Mrz 86						17	21.6	12.4	0	148.8
Apr 86						23.5	31.8	15.2	113.6	147
Mai 86						24.1	31.9	16.3	17	149.2
Jun 86						22.1	30.7	13.5	110	142.8
Jul 86						20.9	30.2	11.6	30.5	153.1
Aug 86						21.6	32.8	10.4	0	192.2
Sep 86						24	31.3	16.8	42.9	124.8
Okt 86						18.2	27.4	9	64.6	112
Nov 86						20.3	28.1	12.5	51.2	79.9
Dez 86						---	---	---	---	---

month						average temp. [°C]	max. temp. [°C]	min. temp. [°C]	precipitation [mm]	pot. evaporation
Feb 87						14.6	26.2	2.9	4.6	81.4
Mrz 87						17.5	30.2	4.8	1.1	124.8
Apr 87						18.3	29.5	7.1	29.3	123.9
Mai 87						---	---	---	---	---
Jun 87						22.3	33	11.6	56.3	124.4
Jul 87						21.1	30.8	11.5	96.6	85.2
Aug 87						21.6	31.7	11.5	0	159.8
Sep 87						21.4	32.2	10.5	58	142.5
Okt 87						16.5	27.7	5.3	7.4	105.9
Nov 87						18.8	26.4	11.2	0	79.6
Dez 87						15.1	25.5	4.7	0	79.2
Jan 88						12.8	23.2	2.4	4.9	82.2
Feb 88						14.6	25.5	3.7	0	116.3
Mrz 88						16.6	28	5.1	8.9	128.1
Apr 88						20.4	31.7	8.1	30.8	165.4
Mai 88						22.4	33.5	11.2	41.6	101.5
Jun 88						22	32.1	11.9	24.9	140.1
Jul 88						21.5	31.4	11.6	66.2	187.9
Aug 88						20.9	30.5	11.2	154.6	104.9
Sep 88						19.5	29.6	9.5	26.2	100.8
Okt 88						17.8	27.8	7.7	7.5	121.2
Nov 88						16.6	28.7	4.6	0	114.3
Dez 88						---	---	---	---	---
Jan 89						15.7	26.6	4.7	2	85
Feb 89						15.7	27.2	4.1	9	99.9
Mrz 89						19.4	33.6	5.1	4.1	138.9
Apr 89						20.8	34.9	6.8	22.5	139.2
Mai 89						20.8	35.5	6.1	9.8	119.8
Jun 89						24.1	36	12.2	13.1	147.3
Jul 89						22.6	34.3	11	30.3	170.7
Aug 89						21.9	32.8	11.1	121.4	136.3
Sep 89						18.7	28.4	8.9	76.8	157.2
Okt 89						18.7	34.2	3.3	7.1	122.5
Nov 89						17.2	29	5.4	7.9	90.6
Dez 89						11.7	21.5	2	15.4	88.6
Jan 90						14.8	25.2	4.4	9.5	104.1
Feb 90						---	---	---	---	---
Mrz 90						---	---	---	---	---
Apr 90						---	---	---	---	---
Mai 90						---	---	---	---	---
Jun 90						24.4	35.6	13.2	85.8	127
Jul 90						21.3	32.7	10	15.3	143.9
Aug 90						21.7	31.5	11.9	179.7	93.4
Sep 90						21.6	29.8	13.4	129.5	213.6
Okt 90						17.1	22.8	11.5	101	90.8
Nov 90						16.5	28.9	4.1	89.6	89.7
Dez 90						16.1	27.9	4.4	0	73.8
Jan 91	18.3	25.4	11.2	0	92.2	19.6	33.3	5.9	0	94.8
Feb 91	18	25.6	10.3	7.6	105.4	19.8	33.7	5.9	0	101.1
Mrz 91	24.1	36.2	12	0	210	19.2	32.2	6.2	9.5	139.6
Apr 91	27.5	37.4	17.5	1.5	224.5	23.1	39.3	6.9	0	144.6
Mai 91	28.5	37.3	19.8	61.5	208.7	23.7	34.1	13.3	0	118.8
Jun 91	26.7	34	19.5	115.3	173.4	22.5	33.7	11.4	280.1	---
Jul 91	23.3	28.2	18.4	314.4	83.5	20.2	29.8	10.5	260.6	110.1
Aug 91	25.3	32.7	17.9	33.5	165	21	32.3	9.7	11.5	138.2
Sep 91	23.1	28.8	17.4	103	108.9	20.8	34.2	7.4	121.1	---
Okt 91	20.7	26.6	14.9	65.5	92.4	18.9	28.9	8.8	503.4	---
Nov 91	17.3	23.7	10.9	2	82.5	17.3	28.3	6.4	19.3	108.5
Dez 91	16.6	22.5	10.7	16	56.3	13.7	23.4	4.1	27	97.9
Jan 92	14.3	19	9.7	69.4	59	12.6	20.4	4.7	671	---
Feb 92	17.4	24.6	10.2	6.8	109.4	18.2	29.1	7.3	29.5	---
Mrz 92	22.5	30.5	14.5	8.2	148	21.4	31.8	11.1	83	---

month	average temp. [°C]	max. temp. [°C]	min. temp. [°C]	precipitation [mm]	pot. evaporation	average temp. [°C]	max. temp. [°C]	min. temp. [°C]	precipitation [mm]	pot. evaporation
Apr 92	23.1	30.9	15.2	113.8	154.8	22.2	30.1	14.2	122.5	---
Mai 92	23.8	30.8	16.8	104.2	140.6	23	30.8	15.2	---	---
Jun 92	26.2	34.6	17.8	52.9	176	25	33.6	16.5	---	---
Jul 92	25.4	31.9	18.9	93.8	151.7	24.7	31.3	18.1	166	---
Aug 92	25.9	33.3	18.5	48.3	169.1	24.4	31.5	17.3	137.7	---
Sep 92	24.2	30.7	17.7	64.1	114.6	23.4	29.9	16.9	105.2	106.6
Okt 92	20.2	26.2	14.3	69.1	85.1	22.3	28.9	15.6	64	---
Nov 92	18.1	25.2	10.9	11	87.6	22.7	30.6	14.9	128	---
Dez 92	18.6	25.6	11.6	13.5	74.8	18.7	24.9	12.5	127	---
Jan 93	---	---	---	---	---	---	---	---	---	---
Feb 93	19.4	28.5	10.2	4	123.3	19.9	29.3	10.5	15	114
Mrz 93	21.6	31.6	11.5	0	176.4	22.3	30.4	14.2	0	88.2
Apr 93	24.6	34.6	14.6	11.5	198.8	23.4	33	13.9	72	170.3
Mai 93	25.7	33.9	17.4	79.5	185.7	23.5	31.6	15.4	0	111.2
Jun 93	25.5	32.1	18.8	309	127.4	25.5	33.5	17.4	8.5	130.4
Jul 93	25	31.3	18.7	67.8	141.4	24.4	32	16.9	105.5	148
Aug 93	25.3	32.2	18.4	72.5	161	23.4	30.5	16.3	189	---
Sep 93	23.6	29.4	17.8	352	101.4	23.7	30.6	16.9	389	---
Okt 93	21.5	28.1	15	61	108.3	21.1	27.7	14.5	229	90.9
Nov 93	18.2	24.5	11.9	24	63.6	18.2	25.6	10.7	15.6	54.6
Dez 93	16.5	24	9	0	76.6	16.8	25	8.7	10.2	64.6
Jan 94	16.2	24.2	8.2	12.5	80.6	16	24.3	7.7	15	92.1
Feb 94	19	27.6	10.5	1.5	112.5	19.6	33.2	6	0	95.3
Mrz 94	21.6	31.1	12.1	5	159.3	21.3	31.7	11	75.5	149.3
Apr 94	24.1	33.1	15	47.5	155.5	23	38.3	7.8	0	144.8
Mai 94	26.3	34	18.5	90.5	170.4	22.8	30.6	14.9	0	139.2
Jun 94	26.6	34.1	19.1	90	174.6	23.7	34.5	12.9	0	153.5
Jul 94	27.1	35.8	18.3	9	207.4	22.2	33.9	10.4	10	97.1
Aug 94	26.2	33.5	18.8	41.5	161.4	15.8	19.9	11.7	0	135.3
Sep 94	23.9	30.5	17.2	127.5	117.2	18.6	26.2	11	0	148.3
Okt 94	22.8	29.7	15.9	101.5	109.5	22.7	10.1	15.4	0	---
Nov 94	21.3	27.9	14.7	4.5	94.3	22	28.9	15.2	8	---
Dez 94	18.6	25	12.1	1	84.8	18.3	26	10.5	0	---
Jan 95	16.1	23.9	8.4	2.5	85.3	18.8	27.6	10.1	0	---
Feb 95	20.1	29.4	10.7	0	130.6	20.2	30.3	10.2	0	---
Mrz 95	23	32.6	13.5	1.5	192	22.6	33.8	11.5	0	---
Apr 95	25.3	35.4	15.1	0	202.3	24.9	37.6	12.3	0	---
Mai 95	29.6	39.2	20	3	226.8	27.9	38.8	17	0	---
Jun 95	27.6	35.5	19.6	12	196.9	27.4	34.4	20.4	0.1	---
Jul 95	26	33.3	18.7	46.5	160.8	24.7	31.4	17.9	19	---
Aug 95	25	31	19.1	209	---	24.8	30.6	19.1	131.1	---
Sep 95	24.7	31.3	18	42	127.9	---	---	---	---	---
Okt 95	22.3	30.8	13.8	14	142.5	---	---	---	---	---
Nov 95	19.5	26.7	12.2	17	---	24	31	17.1	93	---
Dez 95	16.6	23.1	10.1	11	---	18.3	26	10.6	0	---
Jan 96	15.7	26.8	4.5	11	---	18.2	25.2	11.3	---	---
Feb 96	18.4	29	7.8	5.5	---	19.9	30.6	9.2	---	---
Mrz 96	21	31.1	10.8	3.5	---	17.6	25.6	9.5	---	---
Apr 96	23.6	34.4	12.8	5	---	17.2	25.5	9	---	---
Mai 96	27.9	37.4	18.4	5	---	16.3	22.4	10.3	---	---
Jun 96	26.4	34.3	18.5	89.5	---	16.4	23.5	9.3	---	---
Jul 96	26.2	34.1	18.4	24.5	---	17.7	25.2	10.3	---	---
Aug 96	24.9	31.4	18.3	159	---	13.6	18	9.3	---	---
Sep 96	24.9	31.5	18.3	46.5	---	14.4	18	10.7	---	---
Okt 96	21.9	28.8	14.9	19.5	106.2	12.1	22	2.2	23	---
Nov 96	18.6	25.8	11.3	10	86	18.1	24.7	11.4	---	---
Dez 96	16.1	24.5	7.7	0	81.8	17.5	23.7	11.3	---	---
Jan 97						17.5	24	11	---	---
Feb 97						18.7	25.7	11.7	---	---
Mrz 97						19.9	28.2	11.5	---	---
Apr 97						24.7	31.7	17.8	---	---

month		average temp. [°C]	max. temp. [°C]	min. temp. [°C]	precipitation [mm]	pot. evaporation
Jun 97		26	32.3	19.6	---	---
Jul 97		26.8	32.2	21.4	---	---
Aug 97		27.2	34.4	20	---	---
Sep 97		26.7	32.5	21	---	---
Okt 97		26.6	31.8	21.4	0	---
Nov 97		26.4	31.3	21.5	0	---
Dez 97		22.6	28.5	16.8	---	---

App.No.4.: Rio verde river flow gauges Nogal Obscuro, Vigas and Tanlacut

	VIGAS				TANLACUT			
month	max. yield [m^3/s]	min. yield [m^3/s]	average yield [m^3/s]	month-ly yield [10^3m^3]	max. yield [m^3/s]	min. yield [m^3/s]	average yield [m^3/s]	monthly yield [10^3m^3]
Jan 57	---	---	---	---				
Feb 57	---	---	---	---				
Mrz 57	6.11	4.4	5.2	13928				
Apr 57	7.26	4.57	5.61	14547				
Mai 57	7.09	4.04	5.79	15503				
Jun 57	14.89	4.68	6.49	16818				
Jul 57	31.07	3.88	6.51	17459				
Aug 57	6.3	1.7	3.19	8550				
Sep 57	---	---	---	---				
Okt 57	8.2	3.74	4.88	13084				
Nov 57	4.66	3.31	3.93	10185				
Dez 57	5.65	3.53	4.87	13055				
Jan 58	6.18	2.94	5.32	14262				
Feb 58	5.82	3.93	4.85	11745				
Mrz 58	6.11	3.52	4.96	13288				
Apr 58	7.26	4.57	5.6	14528				
Mai 58	17.9	3.49	11.51	30844				
Jun 58	40.5	2.8	8.21	21281				
Jul 58	335	4.59	29.13	78071				
Aug 58	26	9.8	10.84	29029				
Sep 58	275	10.1	21.32	55258				
Okt 58	515	9.3	65.43	175237				
Nov 58	61.1	12.9	21.83	56591				
Dez 58	14.2	10.4	12.91	34587				
Jan 59	---	---	---	---				
Feb 59	---	---	---	---				
Mrz 59	---	---	---	---				
Apr 59	---	---	---	---				
Mai 59	---	---	---	---				
Jun 59	---	---	---	---				
Jul 59	---	---	---	---				
Aug 59	---	---	---	---				
Sep 59	---	---	---	---				
Okt 59	---	---	---	---				
Nov 59	---	---	---	---				
Dez 59	---	---	---	---				
Jan 60	---	---	---	---	---	---	---	---
Feb 60	---	---	---	---	---	---	---	---
Mrz 60	---	---	---	---	---	---	---	---
Apr 60	---	---	---	---	---	---	---	---
Mai 60	9.42	4.8	6.15	16462	---	---	---	---
Jun 60	6.53	4.38	5.25	13615	---	---	---	---
Jul 60	7.85	4.8	5.72	15328	18.8	2.53	5.5	14732
Aug 60	8.63	3.27	4.69	12578	46.78	2.73	4.97	13299
Sep 60	10.2	3.28	5.76	14938	65.47	5.58	20.18	52298
Okt 60	19.24	3.28	4.74	12704	44.68	3.1	10.48	28074
Nov 60	5.04	3.8	4.47	11585	11.72	4.75	6.34	16436
Dez 60	6.17	3.93	5.37	14396	6.02	4.76	5.53	14818
Jan 61	6.3	5.7	5.96	15972	6.18	4.91	5.49	14711
Feb 61	6.22	3.74	4.87	11771	5.24	3.73	4.51	10910
Mrz 61	4.54	3.16	3.84	10281	3.85	2.24	2.72	7291
Apr 61	4.26	2.97	3.38	8761	2.55	0.97	1.7	4419
Mai 61	3.92	2.57	3.09	8270	2.31	0.81	1.22	3270
Jun 61	67.86	2.6	9.52	24682	170.1	0.47	16.6	43030
Jul 61	6.93	2.7	4.02	10772	47.8	7.51	17.82	47733

month	max. yield [m^3/s]	min. yield [m^3/s]	average yield [m^3/s]	month-ly yield [10^3m^3]	max. yield [m^3/s]	min. yield [m^3/s]	average yield [m^3/s]	monthly yield [10^3m^3]				
Sep 61	24.8	3.1	4.45	11541	28.02	3.76	8.84	22910				
Okt 61	5.55	3.55	4.29	11480	14.26	4.5	6.92	18541				
Nov 61	4.91	3.68	4.35	11291	5.97	4.16	4.96	12869				
Dez 61	5.31	4.29	4.76	12749	4.58	3.88	4.27	11431				
Jan 62	5.2	4.1	4.68	12525	4.69	3.54	4.13	11060				
Feb 62	5.07	3.04	4.02	9728	4.15	1.32	2.99	7231				
Mrz 62	4.35	2.88	3.62	9701	2.14	1.24	1.69	4513				
Apr 62	6.23	2.88	3.69	9567	3.5	1.08	1.98	5138				
Mai 62	3.44	2.37	2.72	7281	1.92	0.43	1.16	3094				
Jun 62	4.58	3.17	2.77	7171	4.94	0.17	1.12	2916				
Jul 62	4.21	2	2.9	7768	4.38	0.48	2.07	5550				
Aug 62	2.61	1.9	2.13	5707	0.53	0.05	0.2	535				
Sep 62	6.45	2.24	3.26	8458	15.18	0.24	5.07	13136				
Okt 62	3.54	2.48	2.98	7986	60.75	3	7.64	20473				
Nov 62	42.7	2.77	3.45	8940	7.98	2.56	3.88	10060				
Dez 62	4.88	3.62	4.21	11264	8.55	3.35	4.76	12744				
Jan 63	3.97	2.88	3.49	9357	3.7	2.4	3.09	8271				
Feb 63	3.3	2.51	2.78	6733	2.51	0.98	1.74	4216				
Mrz 63	3.5	2.24	2.57	6884	1.78	0.39	0.86	2299				
Apr 63	2.78	1.82	2.06	5353	0.83	0	0.25	636				
Mai 63	3.94	1.82	2.43	6510	4.27	0	0.22	599				
Jun 63	62.83	1.81	4.31	11171	47.8	0	2.72	7050				
Jul 63	60.88	1.95	6.75	18084	46.89	1.7	7.04	18852				
Aug 63	2.3	1.74	1.92	5149	2.69	0.53	1.28	3441				
Sep 63	7.26	1.74	2.3	5954	9.98	0.51	2.11	5483				
Okt 63	3.02	1.95	2.54	6797	4.17	1.57	2.41	6458				
Nov 63	2.87	2.24	2.53	6555	2.56	1.67	2.03	5274	**NOGAL OBSCURO**			
Dez 63	3.75	2.69	3.15	8437	3.43	1.93	2.86	7656	max. yield [m^3/s]	min. yield [m^3/s]	average yield [m^3/s]	monthly yield [10^3m^3]
Jan 64	3.57	2.68	3.14	8407	3.64	2.47	3.15	8488	---	---	---	---
Feb 64	3.42	1.86	2.44	6110	2.56	1.01	1.74	4353	---	---	---	---
Mrz 64	2.32	1.68	2	5361	1.01	0.5	0.72	1929	---	---	---	---
Apr 64	2.18	1.4	1.73	4490	0.72	0	0.28	731	---	---	---	---
Mai 64	5.22	1.44	1.8	3818	32.23	0	2.01	5379	---	---	---	---
Jun 64	1.9	1.03	1.43	3702	2.97	0.19	1.05	2737	---	---	---	---
Jul 64	70.56	1.17	2.31	6186	44.69	0.47	1.95	5210	---	---	---	---
Aug 64	4.87	1.24	1.75	4682	6	0.27	1.3	3494	---	---	---	---
Sep 64	119.11	1.57	4.53	11747	66.4	1.1	6.75	17488	---	---	---	---
Okt 64	3.41	1.57	1.89	5063	6.65	0.97	3.15	8444	---	---	---	---
Nov 64	2.77	1.57	2.17	5615	25.7	1.24	2.57	6661	0	0	0	0
Dez 64	3.24	2.36	2.82	7548	14.9	3.23	5.29	14176	0	0	0	0
Jan 65	3.25	2.22	2.64	7084	3.71	2.08	3.1	8312	0	0	0	0
Feb 65	2.88	1.88	2.38	5757	2.63	1.36	1.78	4297	0	0	0	0
Mrz 65	2.56	1.51	1.87	5020	12.26	0.72	1.13	3038	0	0	0	0
Apr 65	2.71	1.57	1.92	4973	47.7	0.55	2.66	6885	0	0	0	0
Mai 65	2.49	1.17	1.47	3927	1.91	0.14	0.57	1520	0.82	0	0.01	24
Jun 65	3.41	1.2	1.49	3859	6.77	0	0.98	2542	66.3	0	0.4	1049
Jul 65	7.13	1.23	1.86	4989	14.5	0.73	4.98	13332	12.4	0	0.36	958
Aug 65	62.18	1.3	4.14	11095	56.25	0.66	8.58	22974	71.5	0	3.81	10192
Sep 65	2.11	1.46	1.67	4321	13.28	1.14	3.88	10062	70.6	0	0.34	882
Okt 65	4.34	1.57	2.29	6123	51.06	2.47	7.87	21082	6.4	0	0.17	443
Nov 65	2.44	1.63	2	5185	2.9	1.54	2.3	5964	0	0	0	0
Dez 65	2.55	2.12	2.34	6277	2.64	1.62	2.19	5854	0	0	0	0
Jan 66	2.94	2.12	2.53	6769	2.88	2.05	2.43	6505	0	0	0	0
Feb 66	2.94	2.03	2.47	5966	2.34	1.2	1.84	4464	0	0	0	0
Mrz 66	3.18	1.26	2.09	5591	2.28	0.9	1.74	4671	0	0	0	0
Apr 66	2.96	1.26	1.95	5047	1.28	0.11	0.7	1824	0	0	0	0
Mai 66	30.17	1.06	2.07	5541	27.6	0.03	0.98	2639	295	0	2.02	5419
Jun 66	504.33	1.27	20.67	53571	529.38	0.12	28.57	74065	999	0	24.63	63854

month	max. yield [m^3/s]	min. yield [m^3/s]	average yield [m^3/s]	month-ly yield [$10^3 m^3$]	max. yield [m^3/s]	min. yield [m^3/s]	average yield [m^3/s]	monthly yield [$10^3 m^3$]	max. yield [m^3/s]	min. yield [m^3/s]	average yield [m^3/s]	monthly yield [$10^3 m^3$]
Jul 66	71.6	2.16	8.13	21789	72.8	5.05	16.79	44969	93	0	3.73	9986
Aug 66	38.17	2.02	5.9	15790	50.8	2.6	12.09	32380	44.7	0	2.31	6182
Sep 66	14.3	1.87	3.56	9216	25.3	4.44	9.04	23432	13.5	0	0.52	1358
Okt 66	94.4	1.65	12.69	33997	141.6	3.65	26.5	70976	114	0	11.39	30502
Nov 66	3.71	2.76	3	7766	15.14	4.4	6.76	17530	0	0	0	0
Dez 66	3.34	2.83	3.06	8190	4.53	3.35	3.78	10131	0	0	0	0
Jan 67	3.91	3	3.57	9564	4.67	2.19	3.76	10081	0	0	0	0
Feb 67	3.88	2.5	3.1	7491	3.93	2.08	2.92	7068	0	0	0	0
Mrz 67	4.81	2.87	3.42	9147	3.13	1.31	2.21	5915	0	0	0	0
Apr 67	3.59	2.06	2.5	6496	2.53	0.17	1.11	2881	0	0	0	0
Mai 67	8.77	1.66	2.52	6757	9.6	0.1	0.97	2600	34.5	0	0.46	1231
Jun 67	7.93	1.74	2.48	6427	8.68	0.6	2.22	5746	22.6	0	1.02	2647
Jul 67	4.9	1.76	2.07	5553	14.5	0.74	2.28	6095	13.14	0	0.28	752
Aug 67	338.5	1.76	19.58	52448	339	0.32	28.47	76250	442	0	23.02	61668
Sep 67	540.69	3.05	69.69	180636	562.63	21.6	117.38	304245	632	0	45.77	118641
Okt 67	734.28	4.04	32.14	86089	778	20.81	75.72	202800	1224	0	34.75	93083
Nov 67	7.2	3.77	4.55	11791	28.6	12.2	17.69	45848	18.98	0	0.96	2488
Dez 67	5.41	4.61	5.07	13598	12.2	8.52	10.37	27768	0	0	0	0
Jan 68	6.06	4.93	5.61	15032	9.1	5.85	7.63	20446	0	0	0	0
Feb 68	5.58	4.22	4.86	12172	7.05	4.97	5.99	15004	0	0	0	0
Mrz 68	5.8	3.95	4.66	12483	8.08	3.69	5.66	15176	0	0	0	0
Apr 68	5.39	3.06	4.16	10783	4.8	1.67	2.99	7756	0	0	0	0
Mai 68	5.68	2.28	3.98	10655	14.25	1.85	3.54	9472	37.48	0	0.18	489
Jun 68	8.3	2.39	3.41	8832	27.1	1.26	4.07	10544	150	0	1.63	4217
Jul 68	21.55	2.8	5.27	14124	58.7	5.23	13.32	35691	32.26	0	1.46	3920
Aug 68	30	2.91	5.63	15083	22.5	5	10.12	27105	35.88	0	2.08	5586
Sep 68	261.5	3.47	28.04	72674	216	6	42.27	109559	312.57	0	24.99	64787
Okt 68	38.7	3	6.82	18257	71	8.62	21.63	57929	52.63	0	4.06	10876
Nov 68	4.16	3.07	3.56	9226	8.62	5.71	6.81	17665	0	0	0	0
Dez 68	5.28	4.13	4.85	13008	6.52	4.9	5.66	15171	0	0	0	0
Jan 69	5.6	4.3	5.09	13623	6.61	4.44	5.66	15147	0	0	0	0
Feb 69	5.2	3.3	4.31	10416	4.9	3.25	3.89	9417	0	0	0	0
Mrz 69	5.2	3.3	4.29	11484	4.44	2.96	3.4	9101	0	0	0	0
Apr 69	6.15	2.6	3.64	9438	3.71	1.58	2.67	6920	0	0	0	0
Mai 69	3.27	2.18	2.8	7487	2.4	1.04	1.43	3839	0	0	0	0
Jun 69	9.15	2.18	2.98	7717	11.12	0.47	1.73	4481	5.85	0	0.13	351
Jul 69	157.9	1.77	9.19	24610	138.23	2.48	13.2	35370	135.79	0	7.73	20707
Aug 69	426.5	1.94	29.96	80232	486.18	1.36	51.87	138939	462.4	0	21.81	58422
Sep 69	375	7.13	58.41	151405	465.08	40.4	115.81	300185	312.32	0	35.61	92288
Okt 69	10.2	6.05	7.13	19114	55.61	26	34.26	91761	0	0	0	0
Nov 69	10.2	5.25	6.6	17098	26	13.66	18.09	46892	0	0	0	0
Dez 69	8.02	6.98	7.57	20281	14.4	10.07	12.69	33993	0	0	0	0
Jan 70	9.03	6.46	7.7	20628	12.4	6.65	9.64	25816	0	0	0	0
Feb 70	7.76	5.57	6.84	16540	9.75	6.65	7.73	18699	0	0	0	0
Mrz 70	7.01	5.2	5.95	15938	8.35	5.03	6.01	16099	0	0	0	0
Apr 70	6.17	2.8	4.75	12321	5.13	2.63	3.67	9519	0	0	0	0
Mai 70	7.55	3.24	4.39	11755	3.63	2.37	2.99	8000	2.47	0	0.03	93
Jun 70	382	3.88	12.94	33547	244.5	2.54	12.65	32779	704	0	8.54	22136
Jul 70	133.65	3.44	11.06	29615	165.7	8.2	21.33	57136	216.2	0	6.32	16942
Aug 70	94.41	2.6	9.49	25415	107.8	6.7	21.14	56632	59.08	0	3.25	8704
Sep 70	276.97	4.82	30.49	79019	273.5	10.8	52.32	135620	216.2	0	23.08	59816
Okt 70	65.95	3.72	10.9	29198	124.8	12.5	35.82	95929	75	0	4.18	11195
Nov 70	5.73	4	5.04	13057	12.5	8.42	10.5	27229	0	0	0	0
Dez 70	6.89	5.24	6.05	16201	9.58	7.48	8.53	22846	0	0	0	0
Jan 71	6.57	5.01	5.9	15812	8.82	5.07	7.05	18882	0	0	0	0
Feb 71	6.6	4.4	5.34	12912	6.26	3.2	4.71	11388	0	0	0	0
Mrz 71	5.81	3.95	5.28	14134	4.55	3	3.72	9967	0	0	0	0
Apr 71	6.73	3.45	4.58	11881	5	1.76	3.42	8873	0	0	0	0
Mai 71	19.44	2.91	4.72	12632	19.34	1.5	3.34	8961	0	0	0	0
Jun 71	262.48	2.8	18.46	47852	269.6	1.85	21.68	56191	152	0	15.08	39089
Jul 71	139.47	3.75	12	32131	223.7	6.53	19.01	50929	79.3	0	2.54	6811

month	max. yield [m^3/s]	min. yield [m^3/s]	average yield [m^3/s]	month-ly yield [10^{3}m^3]	max. yield [m^3/s]	min. yield [m^3/s]	average yield [m^3/s]	monthly yield [10^{3}m^3]	max. yield [m^3/s]	min. yield [m^3/s]	average yield [m^3/s]	monthly yield [10^{3}m^3]
Aug 71	193.2	3.95	31.57	84554	171.79	6.36	47.68	127720	244.4	0	24.53	65700
Sep 71	81.78	7.07	13.89	36011	77.27	12.5	33.02	85587	103	0	7.73	20030
Okt 71	79.56	7.6	19.67	52685	103.07	16.93	48.18	129050	83.46	0	12.04	32240
Nov 71	9.42	6.07	7.86	20377	16.93	11.04	13.07	33887	0	0	0	0
Dez 71	10.88	7.86	9.24	24754	11.32	9.6	10.72	28716	0	0	0	0
Jan 72	11.58	7.26	8.56	22925	10.4	7.91	9.3	24914	0	0	0	0
Feb 72	12.37	7	8.97	22483	10.02	5.94	7.65	19157	0	0	0	0
Mrz 72	22.9	6.43	7.72	20692	13.33	4.98	6.1	16347	0	0	0	0
Apr 72	8.06	3.7	5.55	14385	7.14	2.74	3.99	10335	0	0	0	0
Mai 72	6.61	3.3	4.71	12608	5.9	2.75	3.49	9352	0	0	0	0
Jun 72	7.6	4.02	5.69	14737	33.55	5.42	13.81	35800	8.98	0	0.12	309
Jul 72	123.6	3.46	19.51	52261	192	3.45	34.13	91415	112.16	0	15.38	41199
Aug 72	23.6	4.5	8.34	22351	70	16.73	27.65	74069	22.1	0	1.94	5193
Sep 72	5.73	4	4.84	12545	18.35	8	11.27	29205	0	0	0	0
Okt 72	17.6	4.7	6.18	16565	17.75	7.72	10.08	27008	0	0	0	0
Nov 72	6.17	4.28	5.13	13296	7.98	5.21	6.34	16433	0	0	0	0
Dez 72	6.48	5.15	5.94	15923	7.43	5.86	6.51	17431	0	0	0	0
Jan 73	6.66	4.58	5.79	15516	7.71	5.41	6.42	17190	0	0	0	0
Feb 73	6.64	4.61	5.56	13442	6.44	5.2	5.63	13637	0	0	0	0
Mrz 73	5.16	3.8	4.48	11995	5.26	3	3.78	10112	0	0	0	0
Apr 73	5.33	3.38	4.56	11822	4.34	2.63	3.49	9039	0	0	0	0
Mai 73	10.08	3.18	4.19	11214	6.91	2	3.27	8767	9.5	0	0.03	96
Jun 73	271	2.4	18.84	48825	230	1.7	21.09	54657	347	0	13.05	33815
Jul 73	220.5	5.75	27.01	72348	236.5	13.3	48.08	128775	191.1	0	20.13	53914
Aug 73	103.4	4.96	27.23	72944	244.5	11.5	52.81	141455	154.25	0	18.9	50633
Sep 73	53.4	6.7	13.39	34702	93.5	13.5	29.45	76336	25.8	0	2.83	7346
Okt 73	17.6	5.71	9.12	24437	41.3	10.07	17.81	47701	10.5	0	0.49	1322
Nov 73	9.82	5.66	8.02	20793	17.05	8.95	11.74	30441	0	0	0	0
Dez 73	7.42	6	6.81	18237	10.15	8.14	9.02	24167	0	0	0	0
Jan 74	7.26	5.97	6.64	17796	9.13	6.08	7.41	19837	0	0	0	0
Feb 74	6.76	5.21	5.82	14092	7.09	4.67	5.87	14205	0	0	0	0
Mrz 74	5.88	4.37	5.09	13639	5.69	3.71	4.78	12813	5.9	0	0.03	71
Apr 74	6.31	4.03	4.82	12501	5.69	3.22	3.9	10116	0	0	0	0
Mai 74	11.7	3.41	4.63	12394	6.91	2.02	3.54	9484	0	0	0	0
Jun 74	19	3.8	5.29	13704	27.2	2.4	7.62	19746	23.3	0	0.54	1412
Jul 74	26.12	3.63	7.74	20724	34.3	6.29	14.18	37992	19.7	0	2.17	5807
Aug 74	4.56	3.33	3.8	10186	8.36	3.3	4.77	12773	14.7	0	0.06	151
Sep 74	677.2	3.3	40.94	106133	583.18	4.26	60.89	157826	456.83	0	27.29	70740
Okt 74	50.33	4.69	9.83	26336	108.49	21.3	36.85	98706	25.9	0	1.8	4810
Nov 74	5.82	4.79	5.3	13732	21.3	10.21	13.49	34974	0	0	0	0
Dez 74	5.89	4.76	5.48	14678	10.69	8.71	9.63	25785	0	0	0	0
Jan 75	6.59	5.06	5.79	15521	9.69	7.16	8.4	22495	0	0	0	0
Feb 75	5.63	4.06	4.81	11645	7.76	3.77	5.89	14259	0	0	0	0
Mrz 75	5.65	4.06	4.47	11988	4.19	2.72	3.36	9002	0	0	0	0
Apr 75	4.64	3.13	3.79	9823	3.4	2.08	2.63	6823	0	0	0	0
Mai 75	14.04	3.13	4.49	12037	11.97	1.77	3.5	9366	13.81	0	0.15	404
Jun 75	13.28	3.94	5.79	15004	21.87	3.49	7.35	19065	20.01	0	0.49	1265
Jul 75	49.39	3.51	10.6	28384	56.5	3.2	12.4	33225	46.3	0	5.22	13969
Aug 75	43.25	4.75	10.26	27470	161.8	8.2	23.56	63110	56.32	0	3.6	9646
Sep 75	270.5	4.63	45.25	117298	374	16	96.79	250877	246.3	0	32.13	83282
Okt 75	12.32	4.88	6	16074	33.61	15.66	22.87	61256	4.11	0	0.02	64
Nov 75	6.14	4.66	5.54	14367	16	10.98	13.19	34177	0	0	0	0
Dez 75	6.74	5.24	6.06	16218	10.98	9.6	10.32	27643	0	0	0	0
Jan 76	6.55	5.44	5.92	15846	10.07	7.21	8.82	23619	0	0	0	0
Feb 76	5.78	4.38	5.06	12675	7.96	5.75	6.83	17123	0	0	0	0
Mrz 76	6.73	3.96	4.92	13182	8	4.06	5.07	13572	0	0	0	0
Apr 76	4.66	3.42	4.15	10768	5.41	2.52	4.23	10975	0	0	0	0
Mai 76	4.81	3.41	4	10711	3.78	2.22	2.91	7802	0	0	0	0
Jun 76	38.67	3.18	5.77	14961	48.2	1.95	6.65	17236	39.89	0	2.08	5391
Jul 76	---	---	---	---	2163.3	29.6	124.66	333893	1780	0.17	84.16	225416
Aug 76	25.54	5.2	9.56	25621	57.05	13.7	27.82	74500	27.56	0	3.41	9138

month	max. yield [m³/s]	min. yield [m³/s]	average yield [m³/s]	month-ly yield [10³m³]	max. yield [m³/s]	min. yield [m³/s]	average yield [m³/s]	monthly yield [10³m³]	max. yield [m³/s]	min. yield [m³/s]	average yield [m³/s]	monthly yield [10³m³]
Sep 76	48.4	6.45	10.48	27160	65.6	19.6	27.55	71400	64.3	0	6.19	16056
Okt 76	25.2	5.69	10.06	26935	37.45	12.3	19.78	52968	27.6	1.44	5.43	14542
Nov 76	7.64	6	6.75	17489	14.64	11.7	13.34	34587	4.86	0	1.19	3085
Dez 76	7.49	6.76	7.1	19011	15.38	10.82	12.15	32557	1	0	0.11	290
Jan 77	7.25	5.97	6.76	18101	11.39	8.99	10.01	26817	0	0	0	0
Feb 77	7.47	6.32	6.86	16599	11.08	6.22	8.57	20728	0	0	0	0
Mrz 77	6.87	4.64	5.78	15494	6.98	4.79	5.8	15525	0	0	0	0
Apr 77	5.36	4.26	4.96	12866	5.3	4.37	4.95	12825	0	0	0	0
Mai 77	14.42	4.41	5.79	15506	8.8	4.37	5.65	15138	5.1	0	0.02	65
Jun 77	16.72	4.26	6.11	15833	19.1	3.75	6.25	16211	17.33	0	0.89	2295
Jul 77	6.21	4	4.99	13365	17.1	4.27	7.58	20299	0	0	0	0
Aug 77	5.65	3.72	4.15	11119	5.6	2.7	3.35	8965	5.7	0	0.08	211
Sep 77	65	5.03	9.06	23482	61.2	5.2	11.56	29968	86.2	0	3.58	9289
Okt 77	6.46	4.62	5.42	14523	24.1	5.2	10.34	27706	0	0	0	0
Nov 77	5.88	5.08	5.49	14235	10.02	5.79	6.8	17627	0	0	0	0
Dez 77	5.81	4.93	5.27	14112	7.71	5.74	6.46	17309	0	0	0	0
Jan 78	5.75	4.55	4.94	13241	7.03	4.93	5.88	15760	0	0	0	0
Feb 78	5.73	4.21	5.05	12221	6.57	3.63	4.71	11398	0	0	0	0
Mrz 78	6.15	4.26	4.84	12977	7.03	3.54	4.17	11176	0	0	0	0
Apr 78	5.5	3.26	4.43	11471	5.4	2.27	3.37	8736	0	0	0	0
Mai 78	8.58	2.77	3.45	9249	5.24	0.67	2.36	6324	0	0	0	0
Jun 78	15.53	2.75	4.04	10467	55.68	1.59	6.21	16105	0	0	0	0
Jul 78	11.71	2.75	3.66	9799	12.5	1.86	3.73	9982	33.97	0	0.54	1456
Aug 78	26.29	3.56	5.41	14491	24.37	4	7.04	18858	24.8	0	0.88	2360
Sep 78	558.15	3.56	25.18	65258	572	5.97	39.18	101570	328.63	0	15.24	39491
Okt 78	27.57	4.98	8.95	23974	48.56	12.95	29.23	78279	15.46	0	1.38	3688
Nov 78	5.44	4.93	5.17	13402	16.24	8.75	11.14	2887	0	0	0	0
Dez 78	5.51	4.96	5.22	13973	8.99	6.77	7.79	20873	0	0	0	0
Jan 79	5.49	4.88	5.14	13771	7.71	4.82	6.28	16821	0	0	0	0
Feb 79	5.21	4.66	4.85	11731	4.83	3.69	4.26	10300	0	0	0	0
Mrz 79	5.59	4.28	4.88	13081	4.95	2.45	3.91	10483	0	0	0	0
Apr 79	7.12	3.72	4.92	12757	4.56	2.15	3.29	8523	0	0	0	0
Mai 79	5.09	2.98	4.04	10824	3.6	1.73	2.34	6280	0	0	0	0
Jun 79	5.47	2.99	4.23	10965	6.61	1.69	3.43	8895	0	0	0	0
Jul 79	16.1	3.13	3.98	10656	7.7	1.56	2.39	6410	22.3	0	0.18	485
Aug 79	20.7	3.13	4.01	10749	34.42	1.71	4.22	11303	10.9	0	0.34	924
Sep 79	102.68	3.33	10.08	26136	108.4	5.55	20.28	52558	49.02	0	4.11	10646
Okt 79	4.07	2.79	3.14	8424	5.55	2.67	3.5	9370	0	0	0	0
Nov 79	4.12	2.94	3.67	9507	4.45	2.73	3.71	9623	0	0	0	0
Dez 79	5.82	3.59	4.12	11027	7.97	4.13	5.18	13869	0	0	0	0
Jan 80	5.16	3.9	4.53	12120	6.28	4.1	4.76	12740	0	0	0	0
Feb 80	4.96	4.04	4.48	11228	4.78	3.31	4.22	10575	0	0	0	0
Mrz 80	4.55	2.93	3.79	10152	3.84	1.51	2.38	6370	0	0	0	0
Apr 80	3.64	2.94	3.3	8550	2.17	1.48	1.84	4762	0	0	0	0
Mai 80	3.43	2.37	2.91	7798	41.73	1.19	2.67	7146	0	0	0	0
Jun 80	3.51	2.43	2.75	7130	3.79	1.56	2.14	5549	0	0	0	0
Jul 80	3.41	2.24	2.58	6913	1.92	1.34	1.54	4127	0	0	0	0
Aug 80	2.98	2.28	2.57	6894	4.89	1.37	2.82	7551	0	0	0	0
Sep 80	4.8	2.22	2.69	6970	65.66	1.73	8.17	21172	0	0	0	0
Okt 80	9.57	1.97	2.84	7600	30.9	3.38	10.06	26936	0	0	0	0
Nov 80	3.54	2.92	3.19	8258	6.35	3.32	3.99	10335	0	0	0	0
Dez 80	3.25	2.53	2.77	7415	4.15	3.29	3.73	10006	0	0	0	0
Jan 81	4.09	2.69	3.23	8648	5.42	3.39	4.13	11073	5.7	0	0.37	1003
Feb 81	3.43	2.92	3.28	7946	4.29	2.55	3.31	8011	0	0	0	0
Mrz 81	3.37	2.72	3.14	8404	2.76	1.74	2.29	6145	0	0	0	0
Apr 81	21.16	2.66	3.18	8237	96.84	1.21	3.49	9046	28.8	0	0.22	574
Mai 81	45.61	2.78	5.98	16027	60.69	3.1	7.3	19564	12.35	0	0.42	1122
Jun 81	153.51	2.88	14.74	38208	137.6	2.9	30.86	79991	123.76	0	12.6	32672
Jul 81	60.4	3.4	9.04	24202	61.93	11.25	24.28	65037	60.1	0	4.22	11294
Aug 81	4.42	3.1	3.73	9984	19.87	4.9	8.53	22841	2.89	0	0.12	318
Sep 81	18.74	3.33	4.27	11068	41.04	9	17.64	45723	27.5	0	1.13	2944

month	max. yield [m³/s]	min. yield [m³/s]	average yield [m³/s]	monthly yield [10³m³]	max. yield [m³/s]	min. yield [m³/s]	average yield [m³/s]	monthly yield [10³m³]	max. yield [m³/s]	min. yield [m³/s]	average yield [m³/s]	monthly yield [10³m³]
Okt 81	13.56	3.33	4.86	13016	25.08	8	13.4	35881	17.82	0	1.04	2776
Nov 81	3.81	3.26	3.53	9139	8.52	5.44	6.55	16979	0	0	0	0
Dez 81	3.98	3.49	3.69	9886	7.9	5.33	6.47	17335	0	0	0	0
Jan 82	3.81	3.31	3.48	9333	5.86	3.77	4.92	13184	0	0	0	0
Feb 82	4.01	3.3	3.52	8504	4.58	3.16	3.83	9272	0	0	0	0
Mrz 82	4.83	2.99	3.47	9287	8.85	2.42	3.13	8379	0	0	0	0
Apr 82	12.21	2.48	3	7768	3.64	1.46	2.33	6049	6.79	0	0.06	163
Mai 82	3.63	2.49	3	8045	5.24	1.75	2.69	7207	0.98	0	0	11
Jun 82	2.82	2.19	2.41	6234	2.32	0.83	1.2	3100	0	0	0	0
Jul 82	2.85	2.42	2.68	7185	2.89	1.34	1.81	4844	0	0	0	0
Aug 82	2.78	2.42	2.61	6977	2.19	0.84	1.32	3542	6.26	0	0.03	78
Sep 82	3.36	2.4	2.75	7131	8.47	0.78	2.65	6866	1.86	0	0.03	88
Okt 82	5.62	2.61	3.17	8483	28.6	2.36	4.92	13172	10.7	0	0.25	672
Nov 82	2.86	2.53	2.7	7013	2.84	1.84	2.23	5770	0	0	0	0
Dez 82	2.98	2.56	2.76	7393	3.35	2.15	2.75	7366	0	0	0	0
Jan 83	2.94	2.52	2.78	7434	3.84	2.58	3.38	9063	0	0	0	0
Feb 83	3.01	2.51	2.71	6556	3.03	1.05	2.11	5118	0	0	0	0
Mrz 83	2.93	2.13	2.52	6761	1.7	1.05	1.46	3907	0	0	0	0
Apr 83	2.48	1.91	2.19	5668	1.61	0.5	1.07	2779	0	0	0	0
Mai 83	18.8	1.72	2.36	6317	8.07	0.3	1	2686	0.88	0	0.01	18
Jun 83	5.08	1.56	2.04	5292	5.03	0.74	1.5	3879	11.7	0	0.16	421
Jul 83	104	1.7	14.52	38882	102.4	0.99	25.74	68931	125.7	0	10.05	26920
Aug 83	3.25	2.02	2.47	6604	18.12	3.16	10.24	27423	0	0	0	0
Sep 83	7.77	1.85	3.52	9129	42.9	2.01	16.29	42220	6.56	0	0.5	1305
Okt 83	6.02	2.41	2.78	7457	16.43	4.69	7.55	20228	1.63	0	0	7
Nov 83	4.62	2.52	2.98	7739	5.54	3.31	4.52	11713	0	0	0	0
Dez 83	3.18	2.25	2.69	7213	3.73	2.55	3.23	8651	0	0	0	0
Jan 84	3.7	2.71	3.2	8569	4.21	2.45	3.31	8882	0	0	0	0
Feb 84	3.67	2.49	3.06	7664	4.41	1.46	2.86	7162	0	0	0	0
Mrz 84	2.78	2.03	2.43	6513	1.97	1.3	1.56	4183	0	0	0	0
Apr 84	2.33	1.68	2.07	5368	1.61	0.37	1.05	2710	0	0	0	0
Mai 84	2.57	1.68	2.06	5532	5.51	0.28	1.1	2946	3.72	0	0.02	59
Jun 84	2.96	1.64	2.27	5873	6.31	1.33	3.21	8324	0	0	0	0
Jul 84	140.4	1.72	14.94	40024	103	1.4	21.07	56426	91.6	0	10.62	28455
Aug 84	5.83	2.08	2.65	7099	13.55	4.25	7.62	20399	8.9	0	0.31	825
Sep 84	118.8	2.4	28.12	72883	129.6	7.93	51.1	132442	105.2	0	16.96	43961
Okt 84	13.21	2.22	3.74	10014	44.36	11.44	21.43	57390	4.4	0	0.3	799
Nov 84	3.41	2.64	3.18	8253	11.86	6.49	8.9	23066	0	0	0	0
Dez 84	3.73	2.86	3.21	8609	7.34	5.22	6.26	16772	0	0	0	0
Jan 85	3.68	2.81	3.21	8595	6.21	4.15	5.14	13769	0	0	0	0
Feb 85	3.68	2.72	3.22	7799	4.48	2.56	3.3	7989	0	0	0	0
Mrz 85	3.49	2.64	3.07	8212	2.74	1.63	2.3	6152	0	0	0	0
Apr 85	5.23	2.59	3.26	8450	6.27	1.63	3.21	8314	6.4	0	0.02	49
Mai 85	7.79	2.32	3.16	8476	6.9	1.3	2.75	7373	14.75	0	0.45	1197
Jun 85	45.01	2.25	5.52	14312	38.81	1.31	7.55	19570	30.3	0	2.23	5795
Jul 85	89.77	2.89	12.49	33454	72.72	9	20.7	55431	43.6	0	6.13	16421
Aug 85	88.64	3.33	7.33	19630	81.6	4.9	13.36	35784	24.29	0	1.52	4080
Sep 85	5.57	2.52	4.22	10952	11.68	5.88	7.85	20361	0	0	0	0
Okt 85	4.34	3.26	3.55	9515	11.26	4.44	6.94	18590	0	0	0	0
Nov 85	4.25	3.09	3.72	9642	6.41	3.27	4.31	11171	0	0	0	0
Dez 85	4.86	3.88	4.43	11876	6.17	4.12	5.07	13575	0	0	0	0
Jan 86	3.56	2.7	3.01	8072	4.39	3.03	3.52	9436	0	0	0	0
Feb 86	3.99	2.78	3.04	7357	3.26	1.55	2.47	5968	0	0	0	0
Mrz 86	3.7	2.8	3.2	8582	2.08	1.43	1.73	4632	0	0	0	0
Apr 86	11.33	2.44	3.12	8091	12.7	1.06	2.61	6777	0	0	0	0
Mai 86	3.27	1.17	2.29	6124	4.84	1.2	2.27	6071	0	0	0	0
Jun 86	9.06	2.58	3.35	8677	19.5	1.39	6.5	16840	0	0	0	0
Jul 86	3.88	2.37	2.92	7820	19.1	3.48	8.45	22626	0	0	0	0
Aug 86	2.52	2.12	2.35	6291	3.48	1.34	1.85	4961	0	0	0	0
Sep 86	2.78	2.28	2.44	6325	4.54	1.48	2.34	6066	0	0	0	0
Okt 86	17.29	2.63	5	13398	34.64	3.46	10.73	28728	0	0	0	0

month	max. yield [m³/s]	min. yield [m³/s]	average yield [m³/s]	month-ly yield [10³m³]	max. yield [m³/s]	min. yield [m³/s]	average yield [m³/s]	monthly yield [10³m³]	max. yield [m³/s]	min. yield [m³/s]	average yield [m³/s]	monthly yield [10³m³]
Nov 86	3.89	2.37	3.28	8501	6.47	2.63	4.78	12391	0	0	0	0
Dez 86	2.96	2.42	2.71	7263	5.02	2.75	3.4	9095	0	0	0	0
Jan 87	2.93	2.93	2.93	7838	3.24	2.03	2.57	6874	0	0	0	0
Feb 87	2.93	2.93	2.93	7079	2.47	1.64	2.1	5082	0	0	0	0
Mrz 87	2.93	2.93	2.93	7837	2.35	1.53	1.78	4770	0	0	0	0
Apr 87	2.93	2.93	2.93	7584	1.92	1.33	1.64	4247	0	0	0	0
Mai 87	2.93	2.93	2.93	7837	10.7	0.92	1.52	4077	0	0	0	0
Jun 87	10.02	2.12	2.79	7234	6.78	1.07	3.53	9142	0	0	0	0
Jul 87	75.71	1.4	8.76	23458	72.2	1.13	12.09	32387	0	0	0	0
Aug 87	49.19	1.95	5.2	13939	55.2	2.75	12.46	33360	0	0	0	0
Sep 87	6.18	0.81	2.2	5713	4.39	1.58	2.68	6939	0	0	0	0
Okt 87	3.02	2.21	2.5	6692	4.09	1.58	2.24	5999	0	0	0	0
Nov 87	3.11	1.01	2.53	6561	2.39	1.28	1.95	5066	0	0	0	0
Dez 87	2.83	2.36	2.57	6889	2.58	1.88	2.17	5823	0	0	0	0
Jan 88	2.73	2.02	2.26	6064	2.91	1.63	2.07	5556	0	0	0	0
Feb 88	2.73	1.96	2.32	5825	1.88	0.79	1.38	3460	0	0	0	0
Mrz 88	2.49	2	2.16	5798	1.58	0.77	1.17	3145	0	0	0	0
Apr 88	2.97	1.26	2.08	5380	2.04	0.21	1.24	3217	0	0	0	0
Mai 88	3.23	1.04	1.69	4524	---	---	---	---	---	---	---	---
Jun 88	6.28	1.09	1.89	4888	15.6	0.2	3.08	7993	---	---	---	---
Jul 88	15.76	1.4	3.16	8456	13.22	2.09	6.95	18608	---	---	---	---
Aug 88	126.52	1.27	11.37	30453	75	1.88	20.55	55032	---	---	---	---
Sep 88	17.2	1.4	3.69	9576	48.34	3.68	15.57	40354	---	---	---	---
Okt 88	2.03	1.14	1.57	4207	4.89	1.77	3.02	8080	0	0	0	0
Nov 88	2.28	1.53	2.02	5248	2.26	1.49	1.86	4828	0	0	0	0
Dez 88	2.43	2.1	2.27	6080	2.63	1.83	2.35	6301	0	0	0	0
Jan 89	2.3	1.88	2.08	5569	5.7	1.5	2.1	5615	0	0	0	0
Feb 89	2.97	2.02	2.19	5299	1.9	1.05	1.43	3451	0	0	0	0
Mrz 89	2.22	1.55	2.02	5407	1.27	0.64	0.99	2661	0	0	0	0
Apr 89	3.27	1.4	1.87	4850	1.06	0.47	0.71	1853	0	0	0	0
Mai 89	2.33	0.73	1.25	3360	---	---	---	---	0	0	0	0
Jun 89	2.76	0.68	1.34	3472	---	---	---	---	0	0	0	0
Jul 89	2.5	0.9	1.61	4324	1.16	0.14	0.45	1197	0	0	0	0
Aug 89	30.76	0.93	3.78	10116	18.91	0.15	4.45	11920	---	---	---	---
Sep 89	15.35	0.97	2.25	5824	26.9	2.57	6.23	16153	---	---	---	---
Okt 89	2.33	1.01	1.54	4115	6.15	0.69	2.12	5691	0	0	0	0
Nov 89	1.96	1.1	1.7	4418	1.63	0.73	1.08	2788	0	0	0	0
Dez 89	2.44	1.77	2.05	5483	3.11	1.63	2.47	6615	0	0	0	0
Jan 90	2.16	1.59	1.87	5004	2.84	1.55	2.23	5973	0	0	0	0
Feb 90	2.32	1.71	1.99	4818	1.92	0.53	1.22	2946	0	0	0	0
Mrz 90	2.39	0.95	1.71	4579	1.23	0.41	0.93	2497	0	0	0	0
Apr 90	1.81	0.79	1.41	3642	---	---	---	---	0	0	0	0
Mai 90	2.5	0.75	1.37	3680	---	---	---	---	0	0	0	0
Jun 90	1.84	0.74	1.29	3350	---	---	---	---	0	0	0	0
Jul 90	2.18	1.13	1.78	4763	4.84	0.3	2.83	7577	---	---	---	---
Aug 90	210.18	1	7.91	21175	275	1.04	28.63	76695	---	---	---	---
Sep 90	21.95	2.67	5	12956	57.3	16.75	24.29	62966	---	---	---	---
Okt 90	297.26	3.1	11.36	30421	205	12.9	24.03	64368	---	---	---	---
Nov 90	4.56	1.92	2.61	6772	13.27	3.7	6.96	18045	0	0	0	0
Dez 90	3.11	2.36	2.73	7322	4.55	3.02	3.94	10566	0	0	0	0
Jan 91	2.6	1.96	2.25	6029	3.83	1.42	2.49	6680	0	0	0	0
Feb 91	2.3	1.89	2.18	5276	1.48	0.83	1.14	2763	0	0	0	0
Mrz 91	2.45	1.82	2.15	5751	---	---	---	---	0	0	0	0
Apr 91	2.12	1.49	1.8	4664	---	---	---	---	0	0	0	0
Mai 91	2.64	1.2	1.76	4710	---	---	---	---	0	0	0	0
Jun 91	3.45	1.3	1.86	4809	---	---	---	---	0	0	0	0
Jul 91	246	3.26	26.91	72083	202	15.28	44.03	117940	---	---	---	---
Aug 91	29.34	2	3.34	8935	23.68	5.13	10.13	27129	---	---	---	---
Sep 91	162.98	1.36	17.18	44542	84.91	5	30.09	77989	---	---	---	---
Okt 91	297.26	2.95	32.65	87454	308.5	17.67	58.51	156710	---	---	---	---
Nov 91	4.45	1.16	3.83	9921	17.5	8.59	11.49	29779	0	0	0	0

month	max. yield [m³/s]	min. yield [m³/s]	average yield [m³/s]	month-ly yield [10³m³]	max. yield [m³/s]	min. yield [m³/s]	average yield [m³/s]	monthly yield [10³m³]	max. yield [m³/s]	min. yield [m³/s]	average yield [m³/s]	monthly yield [10³m³]
Dez 91	4.64	3.38	3.91	10462	9.79	6.68	8.22	22009	0	0	0	0
Jan 92	4.56	2.94	3.49	9335	9.65	5.71	7.03	18824	14.47	0	0.31	841
Feb 92	5.3	2.97	3.73	9340	8.68	4.51	6.18	15495	0	0	0	0
Mrz 92	3.3	2.89	3.09	8273	4.6	2.1	3.01	8054	0	0	0	0
Apr 92	5.41	2.47	3.67	9523	26.44	1.61	4.6	11929	0	0	0	0
Mai 92	5.36	2.93	4.26	11410	8.56	3.01	4.5	12042	128.3	0	0.15	394
Jun 92	21.95	2.24	5.06	13103	41.35	1.8	8.09	20964	128.3	0	2.49	6449
Jul 92	9.18	2.28	3.49	9342	30.68	1.44	10.82	28982	41.19	0	0.62	1648
Aug 92	16.95	1.95	3.18	8516	23.5	5.02	8.26	22130	7.79	0	0.11	298
Sep 92	3.81	2.36	3.1	8033	16.52	3.8	9.3	24112	5.2	0	0.26	685
Okt 92	21.95	2.43	4.62	12386	37.41	5.72	11.06	29617	17.13	0	0.85	2271
Nov 92	4.17	2.53	3.14	8145	11.57	5.2	6.66	17274	0	0	0	0
Dez 92	3.27	2.13	2.96	7924	5.75	3.58	4.44	11880	0	0	0	0
Jan 93	2.93	2.29	2.62	7009	5.27	2.33	3.72	9955				
Feb 93	3.01	2.68	2.81	6798	4.1	2.45	3.24	7834				
Mrz 93	2.89	2.43	2.7	7227	3.03	1.65	2.49	6667				
Apr 93	2.63	2.16	2.45	6341	2.32	1.34	1.68	4349				
Mai 93	3.44	2.12	2.86	7657	2.96	1.05	2.05	5481				
Jun 93	291.68	1.89	21.15	54814	229.82	0.78	27.85	72181				
Jul 93	167.93	3.24	36.31	97240	176.27	21.61	64.84	173658				
Aug 93	3.76	2.22	2.78	7455	21.61	9.75	15.85	42456				
Sep 93	260.68	2.33	32.51	84271	11.75	11.47	11.75	30459				
Okt 93	107.41	6.17	17.64	47245	11.75	11.75	11.75	31479				
Nov 93	8.11	6.13	6.62	17151	11.75	11.75	11.75	30464				
Dez 93	6.58	4.62	5.65	15145	11.75	11.75	11.75	31479				
Jan 94	49.49	3	16.77	44910								
Feb 94	5.26	4.35	4.74	11461								
Mrz 94	5.53	3.73	4.36	11680								
Apr 94	7.86	3	4.79	12421								
Mai 94	24.28	2.67	4.34	11617								
Jun 94	5.17	2.67	4.06	10531								
Jul 94	4.23	1.22	3.13	8371								
Aug 94	4.79	0	3.54	9483								
Sep 94	13.43	2.58	4.44	11504								
Okt 94	10.02	2.41	3.87	10361								
Nov 94	7.96	2.73	3.88	10047								
Dez 94	4.58	3.38	3.84	10280								
Jan 95									0	0	0	0
Feb 95									0	0	0	0
Mrz 95									0	0	0	0
Apr 95									0	0	0	0
Mai 95									0	0	0	0
Jun 95									0	0	0	0
Jul 95									0	0	0	0
Aug 95									78.94	0	6.68	17882
Sep 95									0.83	0	0.02	57
Okt 95									0	0	0	0
Nov 95									0	0	0	0
Dez 95									0	0	0	0
Jan 96									0	0	0	0
Feb 96									0	0	0	0
Mrz 96									0	0	0	0
Apr 96									0	0	0	0
Mai 96									0	0	0	0
Jun 96									0	0	0	0
Jul 96									8.25	0	0.22	590
Aug 96									59.01	0	3.77	10101
Sep 96									81.21	0	4.11	10665
Okt 96									26.26	0	1.03	2748
Nov 96									0	0	0	0
Dez 96									0	0	0	0

App.No.5.: Estimations on the number of water capturing constructions and their extraction volumes in the Rioverde basin

(a) Number of water capturing constructions and their use (SECRETARIA DE AGRICULTURA 1980)

	shallow wells	wells	springs	without reference	total
sum	191	376	25	5	597
domestic use	42	18	---	---	60
industrial use	---	4	---	---	4
agriculture	89	313	11	---	409
gardening	10	2	2	---	14
municipality	1	---	---	---	1
combined use	26	8	11	---	44
undetermined	23	31	1	5	60
in operation	155	302	23	---	480
out of order	32	72	1	---	106
undetermined	4	1	1	5	11

(b) Extraction volumes from different water sources ($*10^3 m^3/a$) (SECRETARIA DE AGRICULTURA 1980)

	shallow wells	wells	springs	total
sum	16,983.16	53,800.24	3,253.93	74,037.33
domestic use	458.28	2,107.74	192.84	2,758.86
industrial use	0.00	480.59	0.00	480.59
agriculture	15,277.52	49,551.45	2,862.03	67,691.00
gardening	7.10	94.40	0.00	101.50
combined use	1,240.26	1,566.06	199.06	3,005.38

(c) SASAR wells in operation 1999 for the drinking water supply of Rioverde

well	supposed operation time	yield [l/s]	max. permitted extraction volume	volume [$10^3 m^3/a$]	volume [m^3/a] (max. extraction volume)
P3	24 h/d	16-20	28	504.58 - 630.72	883.01
P9	24 h/d	12-18	28	378.43 – 567.65	883.01
P12	24 h/d	28-40	45	883.01 – 1,261.4	1,419.12
P16	24 h/d	16	18	504.58	567.65
P17	24 h/d	8-10	16	252.29 – 315.36	504.58
PSD	24 h/d	25-30	50	788.40 – 946.08	1,576.8
PSM	24 h/d	15-20	36	473.04-630.72	1,135.3
total		**105-134**	**185**	**3,784.32 - 4,856.54**	**6,969.46**

2. PROCEDURES & METHODS

App.No.6.: Determination methods for the different elements

(R.I. = responsible institution: 1 = B.Planer-Friedrich, 2 = laboratory Dra. M.A. Armienta (UNAM, Mexico), 3 = laboratory Prof. Dudel (Tharandt, Germany), 4 = laboratory Freiberg university of mining and technology (section hydrogeology))

element	method	measuring device	description	detection limit	R.I.
location	GPS (global positioning system)	GPS 12 GARMIN			
pH		WTW Universal-Taschen-meßgerät MultiLine P4 with SenTix 97/T pH electrode		0.01 ± 1 digit	1
temp.		WTW Universal-Taschen-meßgerät MultiLine P4 with SenTix 97/T pH electrode		0.1K ± 1 digit	1
cond.		WTW Universal-Taschen-meßgerät MultiLine P4 with TetraCon 325 conductivity cell		± 1 % of measured value ± 1 digit when ambient temperature 15 - 35°C	1
EH	redox potential platinum to Ag/AgCl	WTW Universal-Taschen-meßgerät MultiLine P4 with Pt 4805/S7 probe	measured values had to be readjusted for normal hydrogen electrode (measured value + (-0.7443 * temperature + 224.98)	1 mV ± 1 digit	1
Oxygen	membrane covered galvanic probe	WTW Universal-Taschen-meßgerät MultiLine P4 with CellOx 325 probe		± 0.5% of measured value ± 1 digit when measuring at calibration temp. ± 10K	1
Na, K	AAS				2
Ca, Mg	complexometric titration with EDTA				2
HCO_3	titrimetric	HACH digital titrator	titration of 50ml sample with 0.1n HCl to pH = 4.3 (m-value), consumption of acid is displayed in digital units on the titrator´s counter, consumption [mL] = display/800, HCO_3 [mmol/L] = consumption [mL] * normality * (reference volume [1000mL/L] / submitted volume [50ml])		1
CO_2	titrimetric	HACH digital titrator	titration of 50ml sample with 0.1n NaOH to pH = 8.2 (p-value), consumption of base is displayed in digital units on the titrator´s counter, consumption [mL] = display/800, CO_2 [mmol/L] = consumption [mL] * normality * (reference volume [1000mL/L] / submitted volume [50ml])		1
SO_4	turbidimetric	Hewlett Packard 8452A diode array spectrophotometer	sample with 5-25mg/L SO_4 (diluting) + 5ml solution (25ml Glycerol + 15ml HCl conc. + 150ml deionized water + 50ml Ethanol 95% + 37.5g NaCl) + 130 ± 10mg BaCl, fill up with deionized water to 100ml, stirr 1 min, read absorption measurement at 420nm after 5min	1-100mg/L better 5-25mg/L	2
PO_4	spectophotometric (ascorbin acid method, 890nm)	HACH Spectrophotometer DR / 2000	Orthophosphate reacts with molybdate in acid medium building a phophormolybdate complex that is reduced with ascorbin acid creating an intensive blue color proportional to the phosphate concentration, possible interferences: Cu (>10mg/L), Fe (>50mg/L), SiO_2 (>50mg/L), H_4SiO_4 (>10mg/L), arsenate and H_2S	0 – 2.5 mg/L	1

element	method	measuring device	description	detection limit	R.I.
N-NO_2	spectophoto-metric (diacoting method, 507nm)	HACH Spectrophotometer DR / 2000	Nitrite reacts with sulfanyle acid building a diaconium salt, that reacts with chromotrop acid creating a yellow-pink complex (color intensity proportional to nitrite concentration), possible interferences: Cu, Fe(II) (too low values), Fe(III), Hg, Ag, Bi, Sb, Pb (precipitation)	0-0.300 mg/L	1
N-NO_3	spectophoto-metric (cadmium reduction method, low conc. 507nm, medium conc. 400nm, high conc. 500nm)	HACH Spectrophotometer DR / 2000	Cadmium metal reduces nitrate to nitrite, the following reactions are the same as with N-NO_2, possible interferences: Ca (>100mg/L $CaCO_3$), Cl (>100mg/L), Nitrite	low 0-0.40 mg/L med. 0-4.5 mg/L high 0 – 30 mg/L	1
N-NO_3	Ultraviolet Spectrophoto-metric Screening Method	Hewlett Packard 8452A diode array spectrophotometer	50ml sample + 1ml HCl, measured at 220nm, 2nd measurement at 275nm to exclude influence of organic matter, possible interferences: NO_2, Cr, chlorates, chlorites, organic matter		2
N-NH_3	spectophoto-metric (Nessler´s method, 425nm)	HACH Spectrophotometer DR / 2000	Ammonium reacts with Nessler´s reagent, catalyzed by polyvinyl alcohol dispergencer creating a yellowish color proportional to the NH_3 concentration, mineral stabilizer is added to complexe the sample´s hardness , possible interferences: glycine, alpiphates, amines, aceton, aldehydes, alcohols	0 – 2.50 mg/L	1
Cl	selective electrode	Orion Research Potentiometer Model 407A	add 5M $NaNO_3$ solution (ionic strength (42.5g $NaNO_3$ in 100ml H_2O) adjuster), possible interference: OH^- (OH^- : Cl^- > 80), Br^- (>3*10^{-3}), I^- (5*10^{-7}), S^{2-} (10^{-6}), CN^- (2*10^{-7}), NH_3 (0.12), S_2O_3 (S_2O_3 : Cl = 0.01)		2
F	selective electrode	Orion Research Potentiometer Model 407A			2
Si					2
Li					2
Fe_{ges}	spectophoto-metric (Ferro-Ver method, 510nm)	HACH Spectrophotometer DR / 2000	FerroVer reagent reacts with all soluble and most insoluble iron compounds, reducing them to Fe^{2+} and creates an orange color proportional to the Fe^{2+} concentration, possible interferences: Cl (>185,000mg/L), Ca as $CaCO_3$ (>10,000mg/L), Mg (>100,000mg/L), Mo (>50mg/L)	0-3.00mg/L	1
Fe^{2+}	spectophoto-metric (1,10-Phenantroline method, 510nm)	HACH Spectrophotometer DR / 2000	1, 10 Phenantroline indicator reacts with Fe^{2+} (not Fe^{3+}) creating an orange color proportional to the Fe^{2+} concentration	0-3.0mg/L	1
As	spectophoto-metric	HACH Spectrophotometer DR / 2000			1
As	hydride generation atomic absorption spectrometry HGAAS	Perkin-Elmer 2380 Atomic Spectrophotometer with MHS-10 reaction unit	10ml sample + 20 drops HCl + reducing agent (3%NaBH4 in 1%NaOH) constant input until max. absorption value is exceeded, measurement at 193.7nm	0.0005mg/L	2
heavy metals, REE	ICP-MS	Li, B, Al, Mn, Fe, Cr, Co, Ni, Cu, Zn, Cd, As, Se, Sr, Sb, Ba, Sc, Y, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Tl, Pb, Th, U			3

element	method	measuring device	description	detection limit	R.I.
DDT, DDD, DDE, DDA, Chloro-propylate, Chloro-benzilate, Dicofol, Tetradifon, etc.	serological method (semi-quantitative sorption with artifical antibodies)	EnviroGard DDT ELISA (enzyme linked immuno sorbent assey) test kit	500µL test diluter are filled in small plastic columns with polyclone antibodies on the bottom, 25µL sample and 100µL DDT enzyme conjugate are added; the solution is shaken for 2-3sec., after an incubation time of 15min the small columns are emptied and washed 4 times with deionized water; afterwards 500µL substrate are added; color reaction is stopped with 500µL stopper solution after 3min, the colorization is measured with a photometer at 450nm, intensive blue colors indicating low DDT concentrations in the sample (quantitative determination with a calibration of standard solutions)		1
organo-phosphatic pesticides	solid phase extraction (extraction of chloro-hydrocarbons, triazines, phenylurea-derivates, phosphorous acids, pyrethroids, carbamates, phenoxyalcanecarbon acidesters and similiar pesticides)	BAKER-10 "Solid Phase Extraction"-System; GC-MS	column conditioning: a octadecyl one-way column is put on the BAKER-10 "SPE" system, 6ml n-hexane, 6ml methanol + 6ml deionized water are slowly vacumed through the column, afterwards 1L sample + 10ml methanol (10-15ml/min), the column is washed with 10ml deionized water and vacume dried for 5min; 2ml n-hexane are added, vacumed after 2min reaction time so that the sorbation surface is still covered, another 2ml n-hexane are added, vacumed totally and all is caught in a 4ml vial, a second 4ml vial is filled with the eluate from a double methanol vacum, to both vials hexachlorobenzole is added as internal standard (to be done in the field) lab: further constriction, excessive solvent is blown out with a weak nitrogen stream + few pentane (for water rests) + 0.5ml cylcohexane → GC		1 & 4
organo-chlorine pesticides	solid phase extraction (reproducible extraction of lindane, endrin, methoxychlor and toxaphene, may be also BHC, Heptachlor, Aldrin, Heptachlor Epoxide, Endosulfan, DDE, DDD, DDT and others)	BAKER-10 "Solid Phase Extraction"-System; GC-MS, GC-ECD	column conditioning: a octadecyl one-way column is put on the BAKER-10 "SPE" system, 6ml n-hexane, 6ml methanol + 6ml deionized water are slowly vacumed through the column, afterwards 4ml deionized water are let by gravity through the column, then 200mL sample are vacumed (5ml/min), the column is washed with 1ml deionized water and vacume dried for 5min; two times 0.5ml aliquote (50% hexane / 50% ether) are forced through the column first by gravity then under vacum, both eluates are collected in a 2ml vial and diluted to volume with hexane (to be done in the field) lab: GC-MS, GC-ECD (no sample transfer or evaporation needed)		1 & 4

App.No.7.: Description of applied computer programs

program	description
Joker	statistical program capable of calculating descriptive statistics, group comparisons, correlation analysis, regression analysis, multivariate statistics
PhreeqC 2 (Parkhurst & Appelo)	geochemical modelling program designed to perform a wide variety of low-temperature aqueous geochemical calculations. It is based on an ion-association aqueous model and has capabilities for (1) speciation and saturation-index calculations; (2) batch-reaction and one-dimensional (1D) transport calculations involving reversible reactions, which include aqueous, mineral, gas, solid-solution, surface-complexation, and ion-exchange equilibria, and irreversible reactions, which include specified mole transfers of reactants, kinetically controlled reactions, mixing of solutions, and temperature changes; and (3) inverse modeling, which finds sets of mineral and gas mole transfers that account for differences in composition between waters, within specified compositional uncertainty limits. Moreover version 2 includes capabilities to simulate dispersion (or diffusion) and stagnant zones in 1D-transport calculations, to model kinetic reactions with user-defined rate expressions, to model the formation or dissolution of ideal, multicomponent or nonideal, binary solid solutions, to model fixed-volume gas phases in addition to fixed-pressure gas phases, to allow the number of surface or exchange sites to vary with the dissolution or precipitation of minerals or kinetic reactants, to include isotope mole balances in inverse modeling calculations, to automatically use multiple sets of convergence parameters, to print user-defined quantities to the primary output file and (or) to a file suitable for importation into a spreadsheet, and to define solution compositions in a format more compatible with spreadsheet programs. (http://www.cc.ndsu.nodak.edu/webphreeq/index.shtml)
Rockworks 99 (Rockware Earth Science Software)	integrated geological data management, analysis and visualization program (point mapping, contouring, gridding, solid modelling, volumetrics, strip logs, cross-sections, fence diagrams, stratigraphic block modelling, univariate statistics, bivariate statistics, trivariate statistics, lineation analysis, planar feature analysis, drawdown modelling, hydrogeochemistry, coordinate conversions, 3D visualization, data conversions) (http://www.rockware.com/catalog/pages/rw99.html)
SPlus	statistical program that combines mathematics, advanced data visualization, scientific graphics, and a graphical user interface toolkit to analyze and visualize scientific data (http://www.ocean.odu.edu/ug/sw/splus_sw.htm)
Surfer Win32 (Surfer Software)	3D contouring and surface plotting program (http://www.ssg-surfer.com/html/surfer_overview.html)
TNTmips (Micro Images)	program for integrated GIS (Geographical Information System), image processing, CAD, TIN, desktop cartography, geospacial database management (http://www.microimages.com/)

App.No.8.: Cluster-analysis for the main ions - samples June/July 1999

(clusters from 2 to 30 calculated with the results from June-July 1999 (App.No.24) considering temperature, pH, conductivity, CO_2, HCO_3, K, Na, Mg, Ca, Cl, SO_4, SiO_2, F, NO_3, As; 30 cases with 15 variables
program: SPLUS, method: K-means)

	El REFUGIO												spring	El Refugio	SPRINGS							PASTORA								
name	P3	P16	P9	PSD	P17	El Encinito II	Huerta los Pinos	Chilera	El Peloateado	El Encinito I	P12	Las Guayabas	Ojo de Agua de Solano	Dona Matilde	Anteojitos	Media Luna F	Media Luna E	Media Luna cave	Media Luna D	Media Luna B/C	Media Luna A	Chamizal	Vergel II	Santo Domingo	San Isidro	La Gloria	Rancho 13	Vergel I	Pastora	La Cabana
	1	2	3	4	5	6	7	8	9	10	11	12	30	13	23	24	25	26	27	28	29	14	15	16	17	18	19	20	21	22
number of clusters																														
2	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 23, 24, 25, 26, 27, 28, 29, 30																					14, 15, 16, 17, 18, 19, 20, 21, 22								
3	1, 2, 3, 4, 5, 6, 7							8, 9, 10, 11, 12, 13, 23, 24, 25, 26, 27, 28, 29, 30, 14															15, 16, 17, 18, 19, 20, 21, 22							
4	1, 2, 3, 4, 5, 6, 7							8, 9, 10, 11, 12, 13, 23, 24, 25, 26, 27, 28, 29, 30														14, 15, 16, 17, 18					19, 20, 21, 22			
5	1, 2, 3, 4, 5, 6, 7							8, 9, 10, 11, 12, 13, 23, 24, 25, 26, 27, 28, 29, 30														14	15, 16, 17, 18				19, 20, 21, 22			
6	1, 2, 3, 4, 5, 6						7, 8, 9			10, 11, 12, 13, 23, 24, 25, 26, 27, 28, 29, 30												14	15, 16, 17, 18				19, 20, 21, 22			
7	1, 2, 3, 4, 5, 6						7, 8, 9			10, 11, 12, 13, 23, 24, 25, 26, 27, 28, 29, 30												14	15, 16, 17, 18				19, 20		21, 22	
8	1, 2, 3, 4, 5					6, 7		8, 9		10, 11, 12, 13, 23, 24, 25, 26, 27, 28, 29, 30												14	15, 16, 17, 18				19, 20		21, 22	
9	1, 2, 3, 4, 5					6, 7		8, 9		10, 11, 12, 13, 23, 24, 25, 26, 27, 28, 29, 30												14	15, 16, 17, 18				19, 20		21	22
10	1, 2, 3, 4, 5					6, 7		8, 9		10, 11, 12, 30				13, 23, 24, 25, 26, 27, 28, 29								14	15, 16, 17, 18				19, 20		21	22
11	1, 2, 3, 4, 5					6, 7		8, 9		10, 11, 12, 30				13, 23, 24, 25, 26, 27, 28, 29								14	15, 16, 17, 18				19	20	21	22
12	1, 2		3, 4, 5			6, 7		8, 9		10, 11, 12, 30				13, 23, 24, 25, 26, 27, 28, 29								14	15, 16, 17, 18				19	20	21	22
13	1, 2		3, 4, 5			6, 7		8, 9		10, 11, 12, 30				13, 23, 24, 25, 26, 27, 28, 29								14	15, 16		17, 18		19	20	21	22
14	1, 2		3, 4, 5			6, 7		8, 9		10, 11, 12, 30				13, 23, 24, 25, 26, 27, 28, 29								14	15	16	17, 18		19	20	21	22
15	1, 2		3, 4, 5			6	7	8, 9		10, 11, 12, 30				13, 23, 24, 25, 26, 27, 28, 29								14	15	16	17, 18		19	20	21	22
16	1, 2		3, 4, 5			6	7	8, 9		10, 11, 12, 30				13, 23, 24, 25, 26, 27, 28, 29								14	15	16	17	18	19	20	21	22
17	1, 2		3, 4, 5			6	7	8, 9		10, 11, 12, 30				13, 23, 24, 25				26, 27, 28, 29				14	15	16	17	18	19	20	21	22
18	1, 2		3, 4, 5			6	7	8, 9		10, 11, 12, 30				13	23, 24		25, 26, 27, 28, 29					14	15	16	17	18	19	20	21	22
19	1, 2		3, 4, 5			6	7	8	9	10, 11, 12, 30				13	23, 24		25, 26, 27, 28, 29					14	15	16	17	18	19	20	21	22
20	1, 2		3, 4, 5			6	7	8	9	10, 11		12, 30		13	23, 24		25, 26, 27, 28, 29					14	15	16	17	18	19	20	21	22
21	1, 2		3, 4, 5			6	7	8	9	10, 11		12, 30		13	23, 24		25, 26, 27, 28				29	14	15	16	17	18	19	20	21	22
22	1, 2		3, 4		5	6	7	8	9	10, 11		12, 30		13	23, 24		25, 26, 27, 28				29	14	15	16	17	18	19	20	21	22
23	1	2	3, 4		5	6	7	8	9	10, 11		12, 30		13	23, 24		25, 26, 27, 28				29	14	15	16	17	18	19	20	21	22
24	1	2	3, 4		5	6	7	8	9	10, 11		12, 30		13	23	24, 25		26, 27, 28			29	14	15	16	17	18	19	20	21	22
25	1	2	3, 4		5	6	7	8	9	10, 11		12	30	13	23	24, 25		26, 27, 28			29	14	15	16	17	18	19	20	21	22
26	1	2	3	4	5	6	7	8	9	10, 11		12	30	13	23	24, 25		26, 27, 28			29	14	15	16	17	18	19	20	21	22
27	1	2	3	4	5	6	7	8	9	10	11	12	30	13	23	24, 25		26, 27, 28			29	14	15	16	17	18	19	20	21	22
28	1	2	3	4	5	6	7	8	9	10	11	12	30	13	23	24	25	26, 27, 28			29	14	15	16	17	18	19	20	21	22
29	1	2	3	4	5	6	7	8	9	10	11	12	30	13	23	24	25	26	27, 28		29	14	15	16	17	18	19	20	21	22
30	1	2	3	4	5	6	7	8	9	10	11	12	30	13	23	24	25	26	27	28	29	14	15	16	17	18	19	20	21	22

App.No.9.: Significancy for main ion clusters - samples June-July 1999

(cluster membership from App.No.8; program for variogram analysis: JOKER, method ANOVA; 30 cases with 15 variables, red: > 0.05 = 5% (not significant), *4 cluster* = cluster model taken for interpretation)

number of clusters	2	3	4	5	6
temperature	0.003	0.003	0.005	0.096	0.062
pH	0.573	0.072	0.165	0.625	0.807
conductivity	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
CO_2	0.163	0.001	0.004	0.096	0.004
HCO_3	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
K	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Na	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Mg	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Ca	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Cl	<0.0005	0.006	0.001	0.001	<0.0005
SO_4	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
SiO_2	0.441	0.004	0.035	0.337	0.012
F	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
NO_3	0.826	0.104	0.391	0.690	0.132
As	0.011	0.153	0.067	0.011	0.018

number of clusters	7	8	9	10	*4 cluster*
temperature	0.126	0.216	0.407	0.189	<0.0005
pH	0.589	0.373	0.459	<0.0005	<0.0005
conductivity	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
CO_2	0.019	0.051	0.172	0.072	<0.0005
HCO_3	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
K	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Na	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Mg	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Ca	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Cl	<0.0005	<0.0005	<0.0005	<0.0005	0.002
SO_4	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
SiO_2	0.043	0.086	0.251	0.131	<0.0005
F	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
NO_3	0.170	0.203	0.271	0.253	0.005
As	0.004	0.009	0.046	0.049	0.120

App.No.10.: Selective cluster-analysis for the main ions - samples October 1999

(clusters from 2 to 6 calculated with the results from October 1999 (App.No.24) considering (VC1) temperature, pH, conductivity, CO_2, HCO_3, K, Na, Mg, Ca, Cl, SO_4, SiO_2, F, NO_3 and (VC2) temperature, pH, conductivity, CO_2, HCO_3, K, Na, Mg, Ca, Cl, SO_4, SiO_2, F, NO_3 plus EH, oxygen, NO_2, PO_4, Li;
24 cases with 14 (VC1) respectively 19 (VC2) variables; program: SPLUS, method: K-means)

	El REFUGIO												spring	El Refugio	SPRINGS			PASTORA					
name	P3	P9	PSD	PSM	P 16	P17	El Encinito II	Huerta los Pinos	Chilera	El Peloateado	El Encinito I	P12	Las Guayabas	Ojo de Agua de Solano	Dona Matilde	Charco Azul	Anteojitos	Media Luna	Chamizal	Vergel II	Santo Domingo	Pastora	Rancho 13	Vergel I
	1	3	4	31	2	5	6	7	8	9	10	11	12	30	13	32	23	24-29	14	15	16	21	19	20
number of clusters (same results for VC1 and VC2)																								
2	1, 3, 4, 31, 2, 5, 6, 7, 8, 9, 10, 11, 12, 30, 13, 32, 23, 24-29																		14, 15, 16, 21, 19, 20					
3	1, 3, 4, 31, 2, 5, 6, 7, 8, 9, 10, 11, 12, 30, 13, 32, 23, 24-29																		14, 15, 16, 21				19, 20	
4	1, 3, 4, 31, 2, 5, 6, 7								8, 9, 10, 11, 12, 30, 13, 32, 23, 24-29										14, 15, 16, 21				19, 20	
5	1, 3, 4, 31, 2, 5, 6, 7								8, 9, 10, 11, 12, 30, 13, 32, 23, 24-29										14	15, 16, 21			19, 20	
6	1, 3, 4, 31, 2, 5						6, 7, 8			9, 10, 11, 12, 30, 13, 32, 23, 24-29									14	15, 16, 21			19, 20	

App.No.11.: Significancy for main ion clusters - samples October 1999 (App.No.10)

(cluster membership from App.No.10; program for variogram analysis: JOKER, method ANOVA; 24 cases with 19 variables (VC2, App.No.10), red: > 0.05 = 5% (not significant), *4 cluster* = cluster model taken for interpretation)

number of clusters	2	3	4	5	6	*4 cluster*
temperature	0.054	0.323	0.095	0.398	0.365	0.009
pH	0.028	0.003	0.002	0.038	0.055	0.135
cond	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
EH	0.012	0.130	0.054	0.072	0.061	0.039
O_2	0.163	0.104	0.115	0.457	0.355	0.164
NO_2	0.819	0.531	0.709	0.901	0.923	0.971
PO_4	0.178	0.580	0.392	0.671	0.639	0.350
CO_2	0.500	0.575	0.196	0.499	0.394	0.101
HCO_3	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
K	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Na	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Mg	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Ca	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Cl	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Li	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.006
SO_4	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
SiO_2	0.924	0.967	0.634	0.473	0.473	0.238
F	<0.0005	0.002	<0.0005	<0.0005	<0.0005	<0.0005
NO_3	0.739	0.494	0.576	0.710	0.591	0.164

App.No.12.: Selective cluster-analysis for isotopes - samples July 1999

(clusters from 2 to 6 calculated with the isotopic results from July 1999 (App.No.24), considering Tritium (^{3}H), Deuterium (^{2}H) and Oygen (^{18}O); 20 cases with 3 variables; program: SPLUS, method: K-means)

	El REFUGIO						PASTORA					El Refugio	Pastora		El Refugio	SPRINGS				
name	P9	Chilera	P3	P17	P16	El Peloateado	Vergel II	San Isidro	Vergel I	Pastora	La Cabana	PSD	Santo Domingo	Rancho 13	P12	Ojo de Agua de Solano	Anteojitos	Media Luna F	Media Luna cave	Media Luna B/C
	3	8	1	5	2	9	15	17	20	21	22	4	16	19	11	30	23	24	26	28
number of clusters																				
2	3, 8, 1, 5, 2, 9, 15, 17, 20, 21, 22, 4, 16, 19														11, 30, 23, 24, 26, 28					
3	3, 8, 1, 5, 2, 9, 15, 17, 20, 21, 22											4, 16, 19			11, 30, 23, 24, 26, 28					
4	3, 8		1, 5, 2, 9, 15, 17, 20, 21, 22									4, 16, 19			11, 30, 23, 24, 26, 28					
5	3, 8		1, 5, 2, 9, 15, 17, 20, 21, 22									4, 16, 19			11	30, 23, 24, 26, 28				
6	3, 8		1, 5		2, 9, 15, 17, 20, 21, 22							4, 16, 19			11	30, 23, 24, 26, 28				

App.No.13.: Significancy for isotopes - samples July 1999

(cluster membership from App.No.12; program for variogram analysis: JOKER, method ANOVA; 20 cases with 3 variables; red: > 0.05 = 5% (not significant), *4 cluster* = cluster model taken for interpretation)

number of clusters	2	3	4	5	6	*4 cluster*
Tritium (^{3}H)	0.723	0.499	0.717	0.279	0.279	0.804
Deuterium (^{2}H)	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.026
Oxygen (^{18}O)	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.039

App.No.14.: Selective cluster-analysis for ICP-MS - samples July 1999

(clusters from 2 to 6 calculated with the ICP-MS results from July 1999 (App.No.24), considering Li, B, Al, Mn, Fe, Cr, Co, Ni, Cu, Zn, As, Se, Sr, Ba, Sc, Tl, Pb, Th, U (selection according to significant absolute concentrations); 21 cases with 19 variables program: SPLUS, method: K-means)

<table>
<tr><th></th><th colspan="9">El REFUGIO</th><th colspan="5">SPRINGS</th><th colspan="7">PASTORA</th></tr>
<tr><th>name</th><th>P3</th><th>P16</th><th>P9</th><th>PSD</th><th>P17</th><th>El Encinito I</th><th>Chilera</th><th>El Peloateado</th><th>P12</th><th>Ojo de Agua de Solano</th><th>Anteojitos</th><th>Media Luna F</th><th>Media Luna cave</th><th>Media Luna B/C</th><th>Vergel II</th><th>San Isidro</th><th>Pastora</th><th>Vergel I</th><th>Santo Domingo</th><th>Rancho 13</th><th>La Cabana</th></tr>
<tr><td></td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>10</td><td>8</td><td>9</td><td>11</td><td>30</td><td>23</td><td>24</td><td>26</td><td>28</td><td>15</td><td>17</td><td>21</td><td>20</td><td>16</td><td>19</td><td>22</td></tr>
<tr><td colspan="22">number of clusters</td></tr>
<tr><td>2</td><td colspan="14">1, 2, 3, 4, 5, 10, 8, 9, 11, 30, 23, 24, 26, 28</td><td colspan="7">15, 17, 21, 20, 16, 19, 22</td></tr>
<tr><td>3</td><td colspan="5">1, 2, 3, 4, 5</td><td colspan="9">10, 8, 9, 11, 30, 23, 24, 26, 28</td><td colspan="7">15, 17, 21, 20, 16, 19, 22</td></tr>
<tr><td>4</td><td colspan="5">1, 2, 3, 4, 5</td><td colspan="9">10, 8, 9, 11, 30, 23, 24, 26, 28</td><td colspan="5">15, 17, 21, 20, 16</td><td colspan="2">19, 22</td></tr>
<tr><td>5</td><td colspan="5">1, 2, 3, 4, 5</td><td colspan="4">10, 8, 9, 11</td><td colspan="5">30, 23, 24, 26, 28</td><td colspan="5">15, 17, 21, 20, 16</td><td colspan="2">19, 22</td></tr>
<tr><td>6</td><td colspan="5">1, 2, 3, 4, 5</td><td colspan="3">10, 8, 9</td><td>11</td><td colspan="5">30, 23, 24, 26, 28</td><td colspan="5">15, 17, 21, 20, 16</td><td colspan="2">19, 22</td></tr>
</table>

App.No.15.: Significancy for ICP-MS clusters - samples July 1999

(cluster membership from App.No.14; program for variogram analysis: JOKER, method ANOVA; 21 cases with 19 variables; red: > 0.05 = 5% (not significant), *4 cluster* = cluster model taken for interpretation)

number of clusters	2	3	4	5	6	*4 cluster*
Li 7	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
B 11	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Al 27	0.149	0.193	0.448	0.147	0.161	0.041
Mn 55	0.568	0.612	0.887	0.459	<0.0005	0.193
Fe 54	0.185	0.460	0.718	0.784	0.472	0.627
Cr 52	0.813	0.414	0.790	0.471	0.874	0.185
Co 59	0.239	0.006	0.056	0.088	<0.0005	0.020
Ni 60	<0.0005	<0.0005	<0.0005	<0.0005	0.001	<0.0005
Cu 63	0.512	0.142	0.394	0.086	<0.0005	0.025
Zn 66	0.783	0.335	0.712	0.335	<0.0005	0.109
As 75	0.007	0.011	<0.0005	<0.0005	0.004	0.029
Se 82	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Sr 88	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Ba 138	0.033	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Sc 45	0.102	0.069	0.206	0.006	0.032	0.001
Tl 203	0.016	0.035	0.018	0.031	0.120	0.106
Pb 208	0.420	0.509	0.808	0.564	0.957	0.295
Th 232	0.824	0.271	0.532	0.441	0.778	0.245
U 238	0.246	0.324	<0.0005	<0.0005	<0.0005	0.202

App.No.16.: Ion balances for the samples from June/July and October 1999

(ion balance calculation: (Σcations-Σanions) / (Σcations+Σanions); red: deviation >6%, corrections necessary)

June/July 1999											
[mmol(eq)/L]	K	Na	Mg	Ca	Cl	SO_4	NO_3	HCO_3	ion balance [%]	SO_4	ion balance [%]
Media Luna A	0.09	0.80	5.43	17.56	0.25	18.87	0.02	4.89	-0.338	corrections in order to fit the ion balance	
Media Luna B/C	0.09	0.79	5.28	17.60	0.25	19.60	0.03	4.99	-2.267		
Media Luna D	0.08	0.82	5.67	17.21	0.24	19.65	0.02	4.96	-2.219		
Media Luna E	0.09	0.84	5.43	17.51	0.28	20.22	0.02	4.93	-3.224		
Media Luna F	0.09	0.85	5.48	18.00	0.32	20.43	0.02	5.04	-2.784		
MediaLuna cave	0.09	0.83	5.48	17.26	0.28	19.90	0.03	4.90	-2.974		
Anteojitos	0.09	0.86	5.38	18.53	0.30	21.30	0.02	4.88	-3.168		
Ojo de Agua de Solano	0.09	0.82	4.79	15.99	0.20	16.73	0.03	4.97	-0.547		
Pastora	0.28	2.91	14.86	27.21	0.34	44.56	0.24	3.20	-3.285		
Vergel II	0.29	3.65	22.67	28.72	0.47	37.42	0.21	3.37	14.316	51.27	0.002
La Cabana	0.30	4.10	22.67	28.72	0.51	51.28	0.02	3.64	0.317		
Rancho #13	0.36	5.90	12.59	33.25	2.26	38.77	0.29	3.61	7.394	45.95	-0.001
La Gloria	0.32	3.27	13.35	25.95	1.24	34.91	0.36	3.01	4.091		
San Isidro	0.29	4.54	9.32	29.98	0.96	37.44	0.30	3.22	2.558		
Santo Domingo	0.37	3.88	10.28	26.00	0.48	35.65	0.21	2.87	1.657		
Vergel I	0.41	10.94	13.35	26.70	0.96	42.10	0.40	3.07	4.978		
Chamizal	0.30	2.24	8.77	21.46	1.58	29.28	0.13	3.16	-2.055		
P12	0.08	0.81	5.11	15.14	0.17	16.22	0.02	4.65	0.187		
P17	0.09	0.82	0.69	2.98	0.14	0.16	0.17	3.60	5.851		
P16	0.07	0.64	1.69	3.62	0.11	1.46	0.07	4.06	2.662		
P3	0.05	0.50	1.54	5.16	0.25	2.05	0.70	3.79	3.268		
Doña Matilde	0.09	1.47	4.61	15.04	0.56	18.97	0.67	4.31	-7.223	15.67	0.002
El Peloteado	0.11	1.41	2.33	12.36	0.68	10.15	0.58	4.02	2.486		
El Encinito II	0.09	0.72	2.03	6.25	0.28	4.04	0.33	4.59	-0.760		
El Encinito I	0.09	1.01	4.61	15.04	0.28	15.73	0.17	4.76	-0.462		
Huerta los Pinos	0.13	1.60	1.94	7.10	0.28	5.83	0.42	3.99	1.130		
Las Guayabas	0.08	0.86	5.01	15.38	0.14	16.35	0.02	4.79	0.074		
P9	0.16	1.24	0.65	3.13	0.32	0.29	0.57	3.55	4.429		
PSD	0.09	1.07	0.74	3.28	0.27	0.35	0.27	3.94	3.478		
Chilera	0.12	1.65	2.93	10.92	0.51	10.70	0.47	4.02	-0.262		
October 1999											
[mmol(eq)/L]	K	Na	Mg	Ca	Cl	SO_4	NO_3	HCO_3	ion balance [%]	SO_4	ion balance [%]
P3	0.05	0.65	0.59	4.59	0.42	0.90	1.22	3.99	-5.258		
P9	0.14	1.08	0.44	3.30	0.39	0.32	0.80	3.78	-3.348		
P12	0.08	0.83	4.66	14.79	0.37	15.51	0.04	4.99	-1.318		
P16	0.06	0.36	2.10	4.41	0.17	2.50	0.05	4.31	-0.750		
P17	0.07	0.44	1.59	4.47	0.14	1.94	0.07	4.40	0.226		
PSD	0.08	1.13	0.36	3.26	0.37	0.36	0.35	4.27	-5.116		
PSM	0.11	1.07	0.80	2.20	0.27	0.15	0.26	3.51	-0.122		
Chilera	0.11	2.05	2.63	10.47	0.85	8.18	0.66	3.88	5.871		
El Peloteado	0.11	1.71	1.90	14.10	1.13	11.89	1.56	4.50	-3.444		
El Encinito I	0.09	0.99	4.10	13.70	0.39	12.37	0.31	5.07	1.987		
El Encinito II	0.09	0.68	2.10	6.21	0.27	4.52	0.45	4.68	-4.485		
Doña Matilde	0.09	1.64	3.37	19.65	0.87	15.76	1.11	4.89	4.459		
Huerta los Pinos	0.09	1.85	1.22	7.25	0.56	3.69	1.65	4.26	1.174		
Las Guayabas	0.08	0.83	4.90	15.00	0.31	11.83	0.03	4.76	10.280	15.71	0.001
Media Luna	0.09	0.90	6.10	17.70	0.31	16.70	0.03	5.08	5.715		
Anteojitos	0.09	0.96	5.86	18.36	0.42	18.26	0.02	4.81	3.612		
Ojo de Agua de Solano	0.08	0.83	4.17	14.39	0.34	14.21	0.06	4.94	-0.202		
Charco Azul	0.09	0.97	5.76	17.47	0.39	18.99	0.04	3.64	2.599		
Chamizal	0.29	2.60	9.43	20.94	1.07	28.44	0.18	3.00	0.871		
Pastora	0.25	2.84	15.68	26.60	1.83	42.08	0.24	3.26	-2.186		
Santo Domingo	0.33	4.05	12.11	26.01	5.64	35.98	0.89	2.84	-3.251		
Vergel I	0.45	10.47	14.29	28.39	5.36	51.20	0.91	1.57	-4.827		
Vergel II	0.29	4.62	14.50	26.90	1.97	36.12	0.38	3.25	5.190		
Rancho #13	0.30	6.33	11.71	32.55	12.69	39.16	0.79	3.23	-4.662		

3. INTERPRETATION

App.No.17.: Oxalate extracts - results for simulated silicate weathering - ICP-MS

(extraction solution: 500 ml 0.2 M ammoniumoxalate mixed with 0.2 M oxal acid to pH 3 for 5 g dry sample (5.step of the sequential extraction from SALOMONS & FÖRSTNER (1980); analyzed with ICP-MS; units: µg/L)

outcrop No.	**46**	**drilling**	**13**	**53a**	**53a**	**46**
location	Tuffcone Vergel	Sainacio	Hill Grande	west riverside of the rio verde	west riverside of the rio verde	Tuffcone Vergel
sample	yellowish tuff soil	clay	El Doctor limestone	fresh water limestone	Caliche	redish-white tuff
Ni	277.501	0	0	38.868	31.624	368.265
Cr	21.515	0.8	1.946	0.106	0.433	8.542
Cu	83.584	2.139	0.698	1.299	1.535	136.753
Zn	579.514	40.57	32.611	80.587	31.456	192.742
As	10.851	22.726	13.432	13.554	28.96	2.245
Cd	1.538	0.93	1.49	0	0.036	0.222
Pb	0.884	13.004	0	0.359	0	0
U	0	0.923	11.504	20.179	0	0
TH	2.618	78.641	0.678	0.893	0.709	1.775
Y	0.783	32.173	0.112	0.028	0.049	1.944
La	0.128	32.314	0.071	0.06	0.052	1.072
Ce	0.373	69.298	0.14	0.137	0.077	1.545
Pr	0.07	7.425	0.04	0.006	0	0.423
Nd	0.129	28.447	0.236	0.048	0.096	1.114
Mo	9.961	0.591	0.095	0.612	1.382	7.828
Sr	100.339	61.136	2.84	4.769	5.374	661.576
Ba	962.952	609.185	0	252.961	81.961	631.782
Mn	3501	2080	54	1095	458	1512
Mg	168686	3757	24468	10755	8958	128177
Al	168008	6540	1089	1625	1286	55900
Ca	7738	2341	120	46	0	4476
Fe	241201	11752	2213	3337	4383	81377

App.No.18.: Deionized water extracts - IC

(extraction solution: 500 ml deionized H_2O for 5 g dry sample, analyzed with IC, units in mg/L)

outcrop No.	**35a**	**39**
location	outcrop on the road Rioverde - Pastora	Hill east of Diego Ruiz
sample	gypsum rich chalk	chalk
Cl	11	0.8
SO_4	1530	6.3
Mg	4.6	0.5
Ca	630	58
Li	< 0.05	<0.05
Na	0.2	<0.1
K	1.1	1.1

App.No.19.: Calculation of groundwater recharge

(ETP = potential evapotranspiration, determined in the different meteorological stations; ETA = acutal evapotranspiration, calculated according to TURC and COUTAGNE; runoff & recharge calculated as difference of precipitation P - ETA)

Meteorological Station Rioverde (W 99.9788889; N 21.925)

month	Ø Temp. [°C]	precipitation [mm]	ETP	ETA (TURC)	runoff & recharge (TURC)	ETA (Coutagne)	runoff & recharge (Coutagne)
January	15.7	15.0	84.13	15.79	-0.81	14.903	0.07
February	17.2	5.6	103.85	5.91	-0.30	5.601	0.01
March	20.2	8.9	146.70	9.41	-0.48	8.902	0.02
April	22.6	51.9	160.98	54.72	-2.77	51.265	0.68
May	24.8	47.6	176.95	50.15	-2.55	47.065	0.53
June	25.0	62.2	163.86	65.52	-3.32	61.307	0.90
July	24.0	81.5	147.61	85.77	-4.28	79.886	1.60
August	23.7	71.7	156.23	75.48	-3.79	70.442	1.25
September	22.7	93.3	120.09	98.08	-4.82	91.073	2.19
October	20.5	47.1	103.46	49.63	-2.51	46.517	0.60
November	18.4	14.7	85.81	15.52	-0.79	14.658	0.06
December	16.2	10.0	70.20	10.51	-0.54	9.940	0.03
Year	20.9	509.5	1519.86	536.48	-26.97	501.56	7.95

Meteorological Station Ojo de Agua Seco (W 100.05773; N 21.85)

month	Ø Temp. [°C]	precipitation [mm]	ETP	ETA (TURC)	runoff & recharge (TURC)	ETA (Coutagne)	runoff & recharge (Coutagne)
January	15.5	12.66	---	13.34	-0.68	12.603	0.05
February	17.5	10.06	---	10.60	-0.54	10.026	0.03
March	21.1	13.46	---	14.19	-0.73	13.410	0.05
April	23.9	28.76	---	30.31	-1.55	28.557	0.20
May	25.5	56.07	---	59.07	-3.00	55.354	0.72
June	25.1	111.92	---	117.69	-5.78	109.014	2.90
July	24.0	90.62	---	95.35	-4.73	88.644	1.98
August	23.8	104.91	---	110.32	-5.40	102.252	2.66
September	22.9	121.25	---	127.33	-6.08	117.576	3.67
October	20.6	48.84	---	51.44	-2.60	48.190	0.65
November	18.3	15.83	---	16.68	-0.85	15.756	0.07
December	16.2	14.01	---	14.77	-0.76	13.949	0.06
Year	21.2	628.4	---	661.08	-32.70	615.33	13.05

Meteorological Station Pastora (W 100.059009; N 22.1315315)

month	Ø Temp. [°C]	precipitation [mm]	ETP	ETA (TURC)	runoff & recharge (TURC)	ETA (Coutagne)	runoff & recharge (Coutagne)
January	16.0	10.4	95.83	11.00	-0.56	10.405	0.04
February	17.4	7.6	118.64	7.97	-0.41	7.540	0.02
March	20.4	8.9	157.84	9.35	-0.48	8.850	0.02
April	23.1	22.9	178.83	24.18	-1.24	22.815	0.13
May	24.8	40.5	196.39	42.69	-2.18	40.128	0.38
June	24.9	62.7	192.99	66.02	-3.34	61.763	0.92
July	23.7	65.8	168.16	69.27	-3.49	64.725	1.05
August	23.5	64.1	160.74	67.53	-3.40	63.124	1.01
September	22.8	68.4	128.53	72.03	-3.61	67.245	1.17
October	20.2	41.2	117.88	43.42	-2.20	40.749	0.47
November	18.4	10.2	96.55	10.80	-0.55	10.214	0.03
December	16.3	13.9	86.55	14.65	-0.75	13.834	0.06
Year	21.0	416.7	1698.94	438.91	-22.22	411.39	5.30

Meteorological Station Media Luna (W 100.02318; N 21.8596833)

month	Ø Temp. [°C]	precipitation [mm]	ETP	ETA (TURC)	runoff & recharge (TURC)	ETA (Coutagne)	runoff & recharge (Coutagne)
January	15.6	23.07	76.41	24.31	-1.24	22.892	0.18
February	18.1	5.99	113.39	6.31	-0.32	5.980	0.01
March	22.0	2.44	180.85	2.57	-0.13	2.435	0.00
April	24.4	36.91	191.33	38.89	-1.99	36.586	0.32
May	26.5	72.91	187.58	76.79	-3.88	71.729	1.18
June	26.3	93.46	177.55	98.38	-4.92	91.510	1.95
July	25.1	98.16	159.38	103.29	-5.12	95.931	2.23
August	25.1	69.18	164.03	72.86	-3.68	68.076	1.11
September	23.7	106.99	120.33	112.49	-5.49	104.215	2.78
October	20.2	38.24	111.64	40.28	-2.05	37.835	0.40
November	18.8	11.86	89.71	12.50	-0.64	11.820	0.04
December	16.9	18.22	75.89	19.21	-0.98	18.118	0.10
Year	21.9	577.4	1648.09	607.88	-30.44	567.13	10.31

Meteorological Station El Huizachal (W 99.9114286; N 21.8245496)

month	Ø Temp. [°C]	precipitation [mm]	ETP	ETA (TURC)	runoff & recharge (TURC)	ETA (Coutagne)	runoff & recharge (Coutagne)
January	16.1	56.72	89.00	59.66	-2.94	55.669	1.05
February	18.2	11.91	98.48	12.55	-0.64	11.865	0.04
March	20.0	17.85	133.32	18.82	-0.96	17.765	0.09
April	22.5	36.25	149.15	38.19	-1.95	35.914	0.33
May	23.6	36.68	137.50	38.66	-1.97	36.356	0.33
June	24.2	74.28	151.77	78.20	-3.93	72.960	1.32
July	22.9	90.85	143.17	95.56	-4.71	88.786	2.06
August	22.4	71.32	146.98	75.07	-3.75	70.027	1.29
September	21.8	99.99	135.90	105.08	-5.09	97.386	2.60
October	20.2	69.94	116.45	73.59	-3.65	68.595	1.35
November	20.0	30.12	105.63	31.74	-1.62	29.871	0.25
December	17.7	20.08	84.80	21.16	-1.08	19.956	0.12
Year	20.8	616.0	1492.15	648.29	-32.30	605.15	10.84

App.No.20.: SML script for the calculation of groundwater recharge in relation to altitude

(SML = spatial manipulation language, applied program: tntmips)

```
# -----------------------------------------------------------------
# Temperature in relation to altitude
# -----------------------------------------------------------------
GetInputRaster  (DGM)
GetOutputRaster (TEMP,NumLins(DGM),NumCols(DGM))

t_mess  =  22.8
t_hoehe = 1000

for each DGM
TEMP = t_mess - 0.47 * ((DGM - t_hoehe)/100)

# -----------------------------------------------------------------
# Precipitation in relation to altitude
# -----------------------------------------------------------------
nnull = 98.0
GetOutputRaster (N_REAL,NumLins(DGM),NumCols(DGM))

for each DGM
N_REAL = nnull + (DGM - t_hoehe) * 0.0007 * nnull

# -----------------------------------------------------------------
# Calculation of actual evapotranspiration (Coutagne equation)
# -----------------------------------------------------------------
GetOutputRaster (V_REAL,NumLins(DGM),NumCols(DGM))

V_REAL = ((N_REAL/1000)-1/(0.8+0.14*TEMP)*(N_REAL/1000)^2)*1000

# -----------------------------------------------------------------
# Calculation of groundwater recharge [mm/a]
# -----------------------------------------------------------------
GetOutputRaster(GW_NEU,NumLins(DGM),NumCols(DGM))

for each GW_NEU
GW_NEU = N_REAL - V_REAL

CopySubobjects(DGM, GW_NEU)
```

App.No.21.: Pumping test data

(data from Secretaria de Recursos Hidraulicos 1972, GWT = groundwater table below well head)

WELL 1				**WELL 163**			
N 21.942113 **W** 100.071959	depth: 120 m	static level: 6.10 m	diameter: 6´´	**N** 21.938473 **W** 100.089158	depth: --- m	static level: 4.20 m	diameter: 6´´
	yield: 19.7 l/s	date: 16.06.1972			yield: 19.7 l/s	date: 11.08.1972	
T = 3.534*10^{-3} m^2/s		**T = 3.679*10^{-3} m^2/s**		**T = 0.53*10^{-3} m^2/s**		**T = 1.60*10^{-3} m^2/s**	
drawdown		**recovery**		**drawdown**		**recovery**	
time [s]	GWT [m]	time [s]	GWT [m]	time [s]	GWT [m]	time [s]	GWT [m]
0	6.1			0	4.2		
15	7.53	15	9.0	15	7.09	15	2.89
30	7.86	30	8.66	30	7.94	30	3.74
45	8.22	45	8.54	45	8.64	45	4.44
60	8.32	60	8.38	60	9.15	60	4.95
120	8.53	120	8.12	120	9.97	120	5.77
240	8.83	240	7.96	240	10.38	240	6.18
480	9.01	480	7.74	480	10.56	480	6.36
900	9.22	900	7.52	900	10.74	900	6.54
1800	9.46	1800	7.21	1800	10.59	1800	6.39
3600	9.79	3600	6.89	3600	10.57	3600	6.37
5400	9.96	5400	6.75	5400	10.59	5400	6.39
7200	10.11	7200	6.60	7200	10.53	7200	6.33
9000	10.19	9000	6.52	9000	10.59	9000	6.39
10800	10.29	10800	6.46	10800	10.6	10800	6.4
12600	10.33	12600	6.40	12600	10.63	12600	6.43
14400	10.39	14400	6.36	14400	10.61	14400	6.41
16200	10.44	16200	6.33	16200	10.59	16200	6.39
18000	10.5	18000	6.30	18000	10.59	18000	6.39
19800	10.53	19800	6.27	19800	17.42	19800	14.13
21600	10.59	21600	6.25	21600	17.44		
23400	10.6	23400	6.23	23400	17.44		
25200	10.64	25200	6.20	25200	17.45		
27000	10.67	27000	6.19	27000	17.48		
28800	10.68	28800	6.18	28800	17.47		
30600	10.72	30600	6.18				
32400	10.75	32400	6.18				
34200	10.77	34200	6.18				
36000	10.83	36000	6.18				

WELL 210				**WELL 290**			
N 21.962018 **W** 100.046986	depth: 105 m	static level: 13.26 m	diameter: 6´´	**N** 22.02014 **W** 100.132978	depth: 46.5 m	static level: 14.06 m	diameter: 6´´
	yield: 24.8 l/s	date: 30.08.1972			yield: 17.66 l/s	date: 27.09.1972	
T = 1.90*10^{-3} m^2/s		**T = 2.02*10^{-3} m^2/s**		**T = 4.17*10^{-3} m^2/s**		**T = 8.38*10^{-3} m^2/s**	
drawdown		**recovery**		**drawdown**		**recovery**	
time [s]	GWT [m]	time [s]	GWT [m]	time [s]	GWT [m]	time [s]	GWT [m]
0	13.26	0	21.9	0	14.06	0	17.47
15	14.91	15	19	15	15.8	15	14.41
45		45	18.63	30	16.19	30	14.8
30	15.7	30	18.44	45	16.26	45	14.87
60	16.7	60	18	60	16.36	60	14.89
120	17.36	120	17.65	120	16.71	120	14.79
240	17.92	240	17.5	240	16.88	240	14.68
480	18.69	480	16.78	480	17.04	480	14.61
900	19.23	900	16.13	900	17.27	900	14.52
1800	19.98	1800	15.41	1800	17.11	1800	14.42
3600	20.81	3600	14.68	3600	17.21	3600	14.32
5400	21.18	5400	14.3	5400	17.27	5400	14.27
7200	21.38	7200	14.09	7200	17.34	7200	14.21
9000	21.48	9000	13.93	9000	17.37	9000	14.19
10800	21.52	10800	13.83	10800	17.37	10800	14.16
12600	21.58	12600	13.75	12600	17.38	12600	14.15
14400	21.63	14400	13.7	14400	17.38	14400	14.14

16200	21.72	16200	13.6	16200	17.39	16200	14.13
18000	21.76	18000	13.6	18000	17.4	18000	14.13
19800	21.9	19800	13.6	19800	17.42	19800	14.13
21600	21.82	21600	13.6	21600	17.44		
23400	21.88			23400	17.44		
25200	21.95			25200	17.45		
27000	21.88			27000	17.48		
28800	21.9			28800	17.47		
30600	21.9						
32400	21.9						
34200	21.9						
36000	21.9						

WELL 225				**WELL 146**		**WELL 80**	
N 21.893252 **W** 100.049052	depth: 36 m	static level: 3.51 m	diameter 4´´	**N** 21.952838 **W** 100.046811	depth: 67 m	**N** 21.896073 **W** 100.066701	depth: 37 m
	yield: 18.3 l/s	date: 18.10.1972			yield: 56.9 l/s		yield: 21.8 l/s
T = 0.972*10^{-3} m^2/s		**T = 0.714*10^{-3} m^2/s**		static level: 8.77 m	diameter: 6´´	static level: 2.70 m	diameter: 4´´
drawdown		**recovery**		date: 23.10.1972		date: 16.10.1972	
time [s]	GWT [m]	time [s]	GWT [m]	**T = 3.72*10^{-3} m^2/s**		**T = 1.45*10^{-3} m^2/s**	
0	3.51	0	6.68	**drawdown**		**drawdown**	
15	3.53	15	6.65	time [s]	GWT [m]	time [s]	GWT [m]
30	3.55	30	6.45	0	10.66	0	4.77
45	3.61	45	6.42	15	10.64	15	4.71
60	3.67	60	6.38	30	10.59	30	4.63
120	3.79	120	6.29	45	10.54	45	4.56
240	4.04	240	6.08	60	10.52	60	4.51
480	4.45	480	5.55	120	10.46	120	4.27
900	5.14	900	5.05	240	10.34	240	3.88
1800	5.61	1800	4.25	480	10.02	480	3.39
3600	6.29	3600	3.71	900	9.66	900	3.06
5400	6.56	5400	3.64	1800	9.28	1800	2.91
7200	6.56	7200	3.59	3600	9.13	3600	2.84
9000	6.64	9000	3.55	5400	9.08	5400	2.8
10800	6.67	10800	3.53	7200	9.05	7200	2.77
12600	6.67	12600	3.51	9000	9.04	9000	2.75
14400	6.68	14400	3.5	10800	9.04	10800	2.73
				12600	9.03	12600	2.72
				14400	9.03	14400	2.72
				16200	9.03		

WELL 389		**WELL 395**		**WELL 4**			
N 22.106669 **W** 100.045283	depth: 70 m	**N** 22.115813 **W** 100.087321	depth: 67 m	**N** 21.927936 **W** 100.073662	depth: 80 m	static level: 7.80 m	diameter: 6´´
	yield: 24.86 l/s		yield: 26.2 l/s		yield: 10.4 l/s	date: 08/09.08.1972	
static level: 7.21 m	diameter: 6´´	static level: 35.71 m	diameter: 6´´	**T = 1.97*10^{-3} m^2/s**			
date: 23.11.1972		date: 16.10.1972		**drawdown**		**drawdown**	
T = 12.25*10^{-3} m^2/s		**T = 1.22*10^{-3} m^2/s**		time [s]	GWT [m]	time [s]	GWT [m]
drawdown		**drawdown**		0	7.8	28800	9.67
time [s]	GWT [m]	time [s]	GWT [m]	15	8.38	30600	9.35
0	7.21	0	35.71	30	8.6	32400	9.38
15	7.87	15	37.01	45	8.72	34200	9.4
30	7.95	30	37.17	60	8.79	36000	9.43
45	7.97	45	37.23	120	8.9	36000	9.43
60	7.98	60	37.39	240	8.98	37800	9.45
120	8	120	37.84	480	9.05	39600	9.48
240	8	240	38.15	900	9.09	41400	9.48
480	8.12	480	38.39	1800	9.12	43200	9.51
900	8.2	900	38.66	3600	9.18	45000	9.53
1800	8.31	1800	38.86	5400	9.22	46800	9.54
3600	8.37	3600	38.82	7200	9.25	48600	9.55
5400	8.41	5400	38.84	9000	9.27	50400	9.55
7200	8.43	7200	38.79	10800	9.29	54000	9.55

9000	8.43	9000	38.71	12600	9.3	61200	9.55
10800	8.44	10800	38.73	14400	9.31	64800	9.55
12600	8.44			16200	9.32	68400	9.55
14400	8.45			18000	9.32	72000	9.55
16200	8.45			19800	9.3	75600	9.55
18000	8.46			21600	9.24	79200	9.39
19800	8.46			23400	9.24	82800	9.38
21600	8.47			25200	9.23	86400	9.38
23400	8.46			27000	9.29		

WELL 22				**WELL 23** (observation well for well 22)			
N 22.106669 **W** 100.045283	depth: 48 m	static level: 12.31 m	diameter: 6´´	**N** 22.115813 **W** 100.087321	depth: 50 m	static level: 12.26 m	date: 17.04.1972
	yield: 43.2 l/s	date: 17.04.1972			distance to well 22: 150 m		
T = 5.53*10^{-3} m^2/s				**T = 5.28*10^{-3} m^2/s**			
drawdown				**drawdown**			
time [s]	GWT [m]	time [s]	GWT [m]	time [s]	GWT [m]	time [s]	GWT [m]
0	12.31	18000	19.53	0	12.16	16200	15.2
15	15.15	18900	19.59	0	12.2	18000	15.28
30	15.38	19800	19.77	0	12.26	18900	15.28
45	15.62	20700	19.83	15	12.31	19800	15.35
60	15.71	21600	19.9	30	12.4	20700	15.48
120	16.15	22500	19.98	45	12.49	21600	15.59
240	16.61	23400	20.08	60	12.55	22500	15.64
480	17.07	24300	20.14	120	12.72	23400	15.73
900	17.47	25200	20.21	240	12.92	24300	15.8
1800	18	26100	20.27	480	13.16	25200	15.86
3600	18.38	27000	20.29	900	13.44	26100	15.93
5400	18.56	27900	20.34	1800	13.82	27000	15.98
7200	18.74	28800	20.47	3600	14.18	27900	16.01
9000	19.12	29700	20.47	5400	14.47	28800	16.05
10800	19.26	30600	20.48	7200	14.67	29700	16.08
12600	19.31	31500	20.48	9000	14.79	30600	16.12
14400	19.41	32400	20.2	10800	14.91	31500	16.05
16200	19.48	33300	19.93	12600	15.08	32400	15.85
				14400	15.14	33300	15.76

WELL 351				**WELL 352** (observation well for well 351)			
N 21.999429 **W** 100.045262	depth: 57 m	static level: 17.95 m	diameter: 6´´	**N** 22.001008 **W** 100.046948	depth: --- m	static level: 17.47 m	date: 19.09.1972
	yield: 41.5 l/s	date: 21/22.09.1972			distance to well 351: 39.5 m		
T = 8.35*10^{-3} m^2/s		**T = 7.60*10^{-3} m^2/s**		**T = 5.48*10^{-3} m^2/s**			
drawdown		**drawdown**		**drawdown**			
time [s]	GWT [m]	time [s]	GWT [m]	time [s]	GWT [m]	time [s]	GWT [m]
0	17.95	93600	24.97	0	17.47	41400	19.38
15	19.78	97200	24.93	15	17.47	43200	19.36
30	20.51	100800	24.92	30	17.47	45000	19.36
45	20.56	104400	24.93	45	17.47	46800	19.42
60	20.69	108000	24.95	60	17.47	48600	19.43
120	21.96	111600	24.98	120	17.47	50400	19.45
240	22.58	115200	25.03	240	17.5	52200	19.47
480	22.9	118800	25.03	480	17.68	54000	19.48
900	23.35	122400	25.17	900	17.81	55800	19.5
1800	23.55	126000	25.14	1800	18.01	57600	19.49
3600	23.9	129600	25.23	3600	18.29	61200	19.51
5400	24.11			5400	18.47	64800	19.54
7200	24.18			7200	18.59	68400	19.53
9000	24.39	**recovery**		9000	18.7	72000	19.54
10800	24.46	time [s]	GWT [m]	10800	18.8	75600	19.56
12600	24.55	0	24.7	12600	18.87	79200	19.59
14400	24.59	600	21.1	14400	18.92	82800	19.58
16200	24.65	1500	19.59	16200	18.99	86400	19.58
18000	24.65	2400	19.39	18000	19.01	90000	19.58

19800	24.61	3330	19.24	19800	19.06	93600	19.58
21600	24.64	4200	19.14	21600	19.08	97200	19.6
23400	24.7	5100	19.03	23400	19.11	100800	19.57
25200	24.72	6900	18.89	25200	19.16	104400	19.57
27000	24.77	8700	18.8	27000	19.19	108000	19.57
28800	24.81	10500	18.72	28800	19.22	111600	19.59
30600	24.88	12300	18.69	30600	19.24	115200	19.6
32400	24.86	14100	18.65	32400	19.26	118800	19.61
34200	24.86	15900	18.59	34200	19.28	122400	19.6
36000	24.9	17700	18.56	36000	19.31	126000	19.66
37800	24.89	19500	18.53	37800	19.33	129600	19.69
39600	24.94	21300	18.51	39600	19.36		
41400	24.94	23100	18.5				
43200	24.94	24900	18.48				
45000	25.01	26700	18.46				
46800	24.98	28500	18.44				
48600	24.99	30300	18.42				
50400	25	32100	18.4				
52200	25	33900	18.39				
54000	25.02	35700	18.38				
55800	25.1	37500	18.37				
57600	25.08	39300	18.38				
61200	25.08	41100	18.37				
64800	25.1	42900	18.36				
68400	25.1	44700	18.36				
72000	25.1	48300	18.36				
75600	25.09	102300	18.48				
79200	25.1	105900	18.48				
82800	25.07	109500	18.48				
86400	25.02	113100	18.48				
90000	24.99	116700	18.48				

App.No.22.: Groundwater table data 1972-1999

a) 1972: April-November, SECRETARIA DE AGRICULTURA (no. = well number according to the report; GWT = groundwater table below well head; altitude in m ASL)

no.	W	N	altitude	well depth	yield [l/s]	GWT (April)	GWT (May)	GWT (June)	GWT (July)	GWT (Aug.)	GWT (Sept.)	GWT (Oct.)	GWT (Nov.)
1	-100.072	21.942113	1013.75	120.6	19.7	8.76	5.72	5.78	---	---	6.08	6.33	10.15
2	-100.0814	21.943756	1016.73	120	13	5.7	5.7	6.48	7.68	6.85	6.94	---	---
3	-100.0713	21.932912	1016.26	90	17.9	9.65	9.46	7.4	7.53	6.5	---	7.57	7.44
4	-100.0737	21.927936	1017.33	80	9.3	8.57	9.63	8.13	7.89	7.8	8.09	7.96	9.71
8	-100.0706	21.941356	1012.13	11	15.6	6.45	---	4.84	4.75	4.65	5	---	6.14
13	-100.0621	21.937055	1011.08	12	8.6	5.27	5.52	5.57	5.46	4.29	5.18	4.39	5.45
21	-100.0512	21.942466	1007.35	45	30	17.78	---	---	10.47	10.1	12.64	11.16	17.47
37	-100.0619	21.925665	1008.4	20	28.8	---	---	3.45	3.42	3.5	---	3.49	3.45
46	-100.0695	21.916844	1014.41	36		4.59	5	5.23	5.54	5.17	5.75	5.3	5.25
59	-100.0597	21.913603	1009.47	17	21.1	1.65	2	2.36	2.4	2.07	2.22	2.37	2.62
71	-100.0694	21.905078	1013.15	20	12.2	4.76	5.15	3.05	1.68	1.34	1.46	---	1.48
80	-100.0667	21.896073	1015.73	37	21.8	2.7	5.83	2.98	3.24	1.83	2.52	2.7	2.6
90	-100.0542	21.904802	1008.84	5		3.37	3.62	3.45	3.36	3.11	3.17	3.7	3.61
102	-100.0434	21.901818	1004.69	39	39.7	---	---	1.95	1.74	1.38	1.65	---	---
111	-100.032	21.917194	100.86	14		1.64	2	1.38	1.33	0.88	1.15	1.17	1.29
117	-100.0401	21.925183	1004.47	40	64.45	---	---	5.68	5.52	5.17	5.43	---	5.59
122	-100.0431	21.925071	1007.4	51	32.8	10.76	---	9.78	9.47	9.06	---	---	10.18
138	-100.0352	21.935591	1002.23	60	26.6	7.39	7.05	5.9	5.15	4.98	5.59	6.3	6.36
141	-100.06	21.950306	1006.44	65	14.1	---	---	9.35	8.89	8.61	8.58	8.82	8.67
146	-100.0468	21.952838	1003.79	67	62.7	10.05	11.55	11.46	9.2	8.48	8.27	9.6	11.41
153	-99.98505	21.91058	989.99	4.85	---	4.05	4.11	4.16	4.59	3.98	4.01	3.95	4.51
154	-99.97809	21.909406	988.44	6	---	5.01	5.08	5.03	5.33	5.03	5.25	5.23	4.91
157	-100.0711	21.950464	1011.64	35	---	---	---	7.76	7.7	5.58	---	6.68	7.52
163	-100.0892	21.938473	1017.85	70	20	---	4.44	4.37	---	4.2	---	4.7	4.48
165	-100.086	21.933849	1018.8	14	---	6	6.1	6.5	6.8	6.91	6.2	6.14	7.8
170	-100.0963	21.915193	1030.28	100	19	5.26	5.48	5.91	6.15	4.77	3.56	3.38	3.87
174	-100.0927	21.900418	1022.85	17	9.3	---	---	5.75	6.17	6.16	4.78	4.98	4.93
175	-100.0979	21.90274	1035.52	10	---	4.51	4.72	4.84	4.02	1.62	2.92	2.58	3.79
176	-100.1143	21.898175	1072.03	12	---	0.75	0.8	0.8	0.8	0.82	0.82	0.95	0.81
179	-100.1052	21.924678	1041.95	11.2	---	8	8.15	8.67	7.39	4.7	---	---	5.46
180	-100.1154	21.922632	1050.16	8	8.27	---	3.48	3.46	3	2.1	2.9	2.52	3.62
184	-100.0874	21.953513	1016.28	45	---	1.94	---	2.54	2.64	2.33	2.78	2.81	2.84
191	-100.0865	21.947289	1015.93	55	16	---	---	---	2.05	1.05	2.17	2.46	---
194	-100.0921	21.947025	1023.5	72	16	---	---	4.7	4.76	3.61	---	4.77	4.94
200	-100.1124	21.940399	1037.29	7.58		1.06	1.01	1.61	0.91	0.57	0.28	0.14	1.13
209	-100.0332	21.960719	1003.34	55	---	13.33	14.14	11.84	12.35	10.87	12.28	13.16	12.82
210	-100.047	21.962018	1007.01	105	24.8	---	---	14.66	11.27	13.2	---	14.06	16.46
225	-100.0491	21.893252	1006.95	36	13.4	---	3.74	3.7	3.93	3.08	---	3.57	3.64
231	-100.0655	21.957193	1002.25	---	21.3	---	4.28	---	4.15	3.82	4.41	4.11	4.05
237	-100.0706	21.845406	1061.88	12	---	5.51	---	5.43	6.15	2.44	4.12	4.68	----
238	-100.0538	21.839358	1046.63	5	---	2.3	---	2.04	2.27	0.7	2.22	2.3	---
239	-100.0325	21.823607	1038.65	35	---	---	10.71	10.55	10.76	---	8.91	10.06	---
240	-100.0225	21.827269	1012.62	---	---	---	9.93	9.9	10.11	10.04	9.01	9.08	---
246	-100.088	21.85607	1123.81	10.8	---	---	3.2	3.46	2.79	2.41	2.86	2.97	----
248	-100.0988	21.867637	1075.73	11.32	---	---	4.6	4.15	3.32	---	3.91	4.15	---
251	-99.9655	21.85709	990.87	5	---	---	3.61	---	3.79	3.78	3.35	3.6	3.75
255	-99.89308	21.909164	986.73	25	---	---	12.43	12.54	12.09	12.5	12.37	12.51	12.85
279	-100.111	22.004998	1024.71	20.4	---	---	12.87	---	13.23	12.82	---	11.66	---
280	-100.1016	21.989626	1022.15	58	---	---	---	---	15.16	13.76	14.88	15.52	12.3
285	-100.124	21.998347	1018.74	---	29.3	---	8	---	8.17	6.82	---	6.86	---
288	-100.1237	22.00988	1025.61	---	---	---	---	---	---	---	---	---	---
290	-100.133	22.02014	1027.08	---	17.66	---	---	15.17	15.17	12.43	---	14.24	---
291	-100.1409	22.020625	1030.38	50	26.2	---	---	17.84	18.1	13.22	---	16.83	---
293	-100.1438	22.013631	1031.3	60	---	---	---	---	---	16.28	---	---	---
301	-99.95859	21.921114	984.97	18	---	11.69	11.6	12	11.4	11.48	11.69	11.53	11.42
302	-99.93822	21.915978	985.34	---	---	5.07	5	5.16	5.1	5.11	5.04	5.75	5.68
303	-99.93226	21.910193	984.63	14	---	10.5	---	10.77	10.35	11.88	9.44	9.57	8.85
306	-99.95332	21.926173	985.59	10.5	15.4	---	9.05	9	9	9	9.19	8.06	8.56
311	-99.95419	21.9472	992.84	---	---	11.48	11.6	---	11.84	11.67	11.56	11.64	11.61
312	-99.94297	21.949474	992.5	---	---	---	10.64	10.68	10.76	10.86	10.78	10.94	10.76
313	-99.84198	21.981382	1042.35	14.3	---	12.9	---	12.68	12.9	12.67	12.52	13.09	13.22
314	-99.95509	21.959199	995.43	24	---	11.64	11.45	11.63	11.7	11.71	11.65	11.86	11.64
316	-99.95774	21.971434	997.32	16	---	13	12.83	12.97	12.94	12.95	12.85	10.96	12.88

no.	W	N	altitude	well depth	yield [l/s]	GWT (April)	GWT (May)	GWT (June)	GWT (July)	GWT (Aug.)	GWT (Sept.)	GWT (Oct.)	GWT (Nov.)
319	-99.89909	21.936639	989.29	10	---	6.34	---	6.35	---	6.64	6.33	6.68	6.31
320	-99.86609	21.923849	1023.75	25	---	22.41	---	20.69	22.05	20.46	22.71	22.39	23.69
321	-99.89085	21.908004	987.47	16	---	14.33	---	13.25	13.46	13.16	13.85	14.33	14.41
322	-99.99631	21.948948	993.4	18	---	17.47	19.06	17.38	---	17.18	19	18.55	17.5
324	-99.99725	21.956333	994.91	30	24	---	---	---	---	9.44	9.75	---	9.4
326	-100.0014	21.964189	998.71	14	---	11.87	11.43	11.63	---	11.78	11.85	11.69	11.48
333	-100.0249	21.958722	1001.64	---	---	16.73	16.8	16.38	---	15.9	10.91	14.28	14.07
337	-100.0334	21.986662	1003.36	---	17	---	17.56	16	17.65	15.52	16.65	14.35	13.7
344	-100.0405	21.970534	1005.52	35	---	17.21	17.28	---	17.2	16.07	16.65	17.04	14.87
349	-100.0303	21.969812	1002.98	70	39.4	---	---	16.18	17.01	18.92	17.4	16.33	15.54
350	-100.0446	21.978159	1006.07	---	46.7	---	---	18.55	17.8	17.22	---	19.15	15.75
351	-100.0453	21.999429	1004.68	57	41.5	---	---	17.2	---	18.15	18.6	17.35	14.74
352	-100.0469	22.001008	1004.7	---	---	---	---	16.91	17.6	15.77	16.04	16.82	14.25
353	-100.0356	21.993966	1003.35	---	---	12.06	12.17	11.8	---	12.06	11.95	11.93	9.82
354	-100.0363	21.975076	1008.95	---	---	19.53	18.17	17.23	17.71	16.87	16.65	17.74	15.6
356	-100.0589	21.979301	1009.12	77	60.6	---	---	17.11	---	14.92	16.55	14.94	19.17
361	-100.0742	21.9736	1012.93	---	---	8.59	19.07	18	18.25	17.43	17.27	18.84	16.6
363	-100.063	21.973448	1012.09	---	---	---	---	---	---	---	---	---	---
365	-100.0816	21.980326	1012.5	40	---	16.41	17.04	15.7	15.69	15.2	15.13	13.05	13.55
367	-100.0755	21.973267	1014.37	70	---	5.7	4.6	4.75	4.86	4.72	4.29	---	4.66
371	-100.043	22.018428	1009.11	70		---	10.33	10.5	10.41	10.44	10.39	10.38	8.56
378	-100.0873	22.009542	1016.66	35	36	---	12.16	10.77	11.65	10.82	---	11.27	---
381	-99.86034	22.070845	1019.49	100	---	---	9.05	8.95	9.33	9.31	9.16	9.44	9.48
382	-99.86129	22.078124	1024.77	14	---	---	12.87	12.75	11.97	12.88	15.81	13.44	13.97
384	-99.90122	22.163625	1022.55	4.25	45.5	---	---	0.69	2.3	1.02	1.74	1.18	1.1
385	-99.90327	22.156018	1024.48	9	---	---	4.08	4.15	4.17	4	3.8	4.2	4.2
387	-99.87986	22.205347	1033.54	10.5	---	---	8.55	---	8.66	8.42	8.27	8.72	8.73
388	-100.0306	22.103568	1014.94	17	---	---	7.53	8.65	8.43	8.48	8.75	8.5	8.5
390	-100.0633	22.104123	1022.19	40	15.83	---	---	---	---	---	12.54	12.04	14.23
391	-100.0692	22.099555	1030.58	---	29.3	---	---	---	---	---	---	---	---
393	-100.0591	22.080245	1016.07	---	60.6	---	---	---	---	---	---	---	---
394	-100.0538	22.081925	1015.38	---	37.9	---	---	6.2	7.11	6.93	7.29	7.29	---
395	-100.0873	22.115813	1045.61	67	26.2	---	35.48	---	35.6	35.63	36.02	---	35.49
396	-100.0576	22.136667	1017.33	33	30.6	---	9.83	8.95	8.9	8.67	8.77	8.84	8.88
398	-100.0762	22.150671	1020.3	40	63	---	12.58	11.11	12.64	---	11.58	11.45	11.46
399	-100.0367	22.162237	1020.05	7.6	63	---	4.82	4.52	5	4.3	5.32	4.97	5.02
400	-100.0394	22.171323	1020.47	7	9.6	---	4.58	4.59	4.9	4.58	3.92	4.81	4.76
402	-100.0111	22.194051	1023.02	7	---	---	2.56	2.52	2.59	2.5	2.47	2.6	2.69
404	-100.0184	22.251074	1029.67	6	12.13	---	5.68	5.9	5.03	5.3	5.55	5.05	5.04
406	-100.0079	22.248237	1030.32	16.1	---	---	---	4.76	4.88	4.55	5.35	---	5.39
408	-99.98769	22.232465	1027.78	45	---	---	---	3.92	3.83	3.69	3.78	3.81	3.74
409	-99.98533	22.224882	1026.16	40	12.2	---	---	---	---	3.83	3.72	3.86	2.18
410	-99.94724	22.247072	1028.44	5	---	---	2.48	2.45	2.42	2.4	2.52	2.62	2.7
411	-99.9539	22.221715	1026.57	45	---	---	2.49	2.61	2.84	2.6	2.9	3	3
412	-99.95804	22.200965	1035.67	45	---	---	2.83	2.9	2.95	2.65	3.04	3.08	3.12
429	-100.2035	22.177526	1107.69	7	---	---	4.36	4.13	4.5	4.39	4.67	4.23	4.21
430	-100.1999	22.192972	1099.64	8.5	10.2	---	4.08	4.08	4.2	4.08	4.4	4.51	4.51
431	-100.1972	22.182121	1100.01	---	---	---	2.77	2.61	2.67	2.59	3.04	3.06	3.08

b) 1973: ALVARADO (no. = well number according to the report; GWT = groundwater table below well head; altitude in m ASL)

no.	W	N	altitude	well depth	yield [l/s]	GWT
1	-100.071959	21.942113	1013.75	120.6	19.7	8.76
3	-100.071345	21.932912	1016.26	90	13	7.53
4	-100.073662	21.927936	1017.33	80	17.9	8.09
21	-100.051191	21.942466	1007.35	45	30	18.89
37	-100.061854	21.925665	1008.4	20	18.8	4.57
46	-100.069533	21.916844	1014.41	36	30.7	6.94
59	-100.05969	21.913603	1009.47	17	18.9	4.17
71	-100.069372	21.905078	1013.15	20	12.2	3.71
80	-100.066701	21.896073	1015.73	37	21.8	9.25
102	-100.043415	21.901818	1004.69	39	38.7	5.34
111	-100.03195	21.917194	100.86	14	9.6	1.47
117	-100.040088	21.925183	1004.47	40	64.45	6.73

no.	W	N	altitude	well depth	yield [l/s]	GWT
122	-100.043091	21.925071	1007.4	51	32.8	9.78
138	-100.035237	21.935591	1002.23	60	26.6	7.03
141	-100.060031	21.950306	1006.44	65	14.1	10.81
146	-100.046811	21.952838	1003.79	67	62.7	10.51
163	-100.089158	21.938473	1017.85	70	12.6	4.2
170	-100.0963	21.915193	1030.28	100	19	6.82
174	-100.092677	21.900418	1022.85	17	9.3	11.62
180	-100.115408	21.922632	1050.16	8	8.27	3.75
191	-100.086457	21.947289	1015.93	55	16	10.86
194	-100.09205	21.947025	1023.5	72	16	11.07
210	-100.046986	21.962018	1007.01	105	24.8	18
225	-100.049052	21.893252	1006.95	36	13.4	8.08
231	-100.065539	21.957193	1002.25	---	21.3	4.69
285	-100.124012	21.998347	1018.74	---	29.3	7.3
290	-100.132978	22.02014	1027.08	---	17.66	15.17
291	-100.140939	22.020625	1030.38	50	26.2	16.83
306	-99.953323	21.926173	985.59	10.5	15.4	9.05
324	-99.997253	21.956333	994.91	30	24	9.62
337	-100.033363	21.986662	1003.36	---	17	16.21
349	-100.030253	21.969812	1002.98	70	39.4	17.4
350	-100.044626	21.978159	1006.07	---	46.7	18.61

c) 1980: SECRETARIA DE AGRICULTURA (no. = well number according to the report; GWT = groundwater table below well head; altitude in m ASL)

no.	W	N	altitude	well depth	yield [l/s]	GWT (static)	GWT (dynamic)
7	-100.077986	21.938939	1016	50	14	10.58	15.64
8	-100.070553	21.941356	1012	50	8	12	17
9	-100.069068	21.942058	1011	19	8	10.76	13.82
15	-100.066032	21.929892	1012	44	30	15.16	21
21	-100.051191	21.942466	1007	46	29.2	13.12	26.01
22	-100.049569	21.941785	1006	52	30	12.7	18.1
23	-100.050557	21.941144	1007	57	36	12.74	21.15
24	-100.048523	21.943061	1006	60	36	12.2	21
34	-100.05382	21.930953	1007	25	12	11.48	14.82
35	-100.053182	21.929129	1007	26	8	10.65	---
36	-100.055559	21.93071	1007	27	15	10	15
37	-100.061854	21.925665	1008	23	10	10.18	15.06
38	-100.053036	21.926823	1007	20	10	10.33	15
43	-100.053632	21.92405	1008	20	18	7	15
51	-100.066825	21.908125	1012	20	8	7.85	14
53	-100.064375	21.912065	1011	20	11.5	8.71	10.91
54	-100.061525	21.91036	1010	25	10.4	9	11
55	-100.052116	21.914867	1008	20	4.4	6	8.25
59	-100.05969	21.913603	1009	22	10	13	19
68	-100.054462	21.913063	1008	20	7	5.9	9
71	-100.069372	21.905078	1013	20	8	7.41	9
73	-100.087372	21.898523	1022	12	15	8.64	11
74	-100.061334	21.903135	1011	20	16	5	7.99
76	-100.057371	21.904951	1009	20	8	6.69	10
77	-100.054933	21.903468	1009	20		8.29	12
79	-100.065885	21.900634	1013	25	12	9	15
84	-100.043534	21.907948	1005	20	30	6	10
93	-100.047895	21.902191	1006	18	---	5.78	---
96	-100.043616	21.896678	1005	25	5	3.81	---
98	-100.039709	21.897802	1004	20	12	4.09	---
101	-100.040503	21.904992	1003	14	14.7	4.32	5.78
102	-100.043415	21.901818	1004	20	10.2	6.43	---
103	-100.039249	21.910723	1003	20	8	5.43	---
123	-100.039027	21.931402	1004	25	25	9.91	---
125	-100.064282	21.942207	1010	50	9	9.9	---
132	-100.041585	21.925674	1005	20	8	9.58	---
139	-100.036477	21.93807	1002	30	36	9.97	---
140	-100.034931	21.929741	1002	15	8	6.8	---
141	-100.060031	21.950306	1006	20	---	13.75	---
143	-100.056993	21.951192	1006	20	8	12	---

no.	W	N	altitude	well depth	yield [l/s]	GWT (static)	GWT (dynamic)
144	-100.035747	21.946438	1002	40	35	12	24.9
145	-100.032706	21.949747	1002	40	32.6	14	20.49
157	-100.071135	21.950464	1011	36	9	12	18
158	-100.072819	21.951029	1012	45	10.2	12	17.54
183	-100.085322	21.952303	1015	27	---	7.7	---
184	-100.087411	21.953513	1016	30	7	8.7	15.47
185	-100.09279	21.953035	1020	45	8	11.8	---
186	-100.09095	21.949103	1020	72	20	10.68	---
187	-100.088108	21.950991	1017	50	8	9.33	22.65
189	-100.08089	21.950385	1014	30	17.2	6.99	15.57
190	-100.078341	21.950402	1013	30	10	7.12	---
191	-100.086457	21.947289	1015	30	28	8.9	---
192	-100.087882	21.946748	1017	30	7	9	18
194	-100.09205	21.947025	1023	30	---	11.7	---
195	-100.087862	21.944574	1017	17	8.3	7.5	15.2
196	-100.082537	21.946918	1016	20	8	7.49	---
197	-100.083108	21.948836	1016	41	10.2	7	15
205	-100.042036	21.95414	1003	50	50	15	---
206	-100.030214	21.954768	1002	70	50.5	20.05	26.1
209	-100.033206	21.960719	1003	70	50.5	20.65	26
215	-100.106126	21.963035	1029	36	5	10.72	16
224	-100.046711	21.888542	1007	14	4	7.04	---
228	-100.096195	21.934716	1026	26	10	8.1	---
231	-100.065539	21.957193	1002	15	---	12.6	---
250	-99.903028	21.888507	---	4	---	3.5	---
251	-99.965501	21.85709	990	7	---	6	---
253	-99.906497	21.890594	---	7.15	---	6	---
255	-99.893082	21.909164	987	78	15	12	---
280	-100.101624	21.989626	1022	17	12.2	10.9	12.25
291	-100.140939	22.020625	1030	60	31.5	20	30.5
298	-100.035196	21.927294	1002	30	10	8.01	---
300	-100.086952	21.913579	1024	30	10	9.85	---
301	-99.958587	21.921114	984	12	25	10.3	---
302	-99.938217	21.915978	985	30	68.2	0	8.4
303	-99.932262	21.910193	984	10.4	---	8.6	---
304	-99.950855	21.923398	985	10	20.5	8.6	---
305	-99.962814	21.921588	985	8	64	---	---
306	-99.953323	21.926173	985	10	25	8.4	---
307	-99.952544	21.930554	986	10	10	8.35	---
308	-99.955813	21.92595	986	9.45	30	8.45	---
310	-99.947275	21.932846	987	8	9	6.5	---
311	-99.954186	21.9472	992	30	11.5	11	---
312	-99.942969	21.949474	992	14.25	6	9.85	---
313	-99.841982	21.981382	1042	15.2	---	14.8	---
314	-99.955092	21.959199	995	11.63	16	8.63	---
315	-99.955286	21.966582	996	80	50	9.4	---
316	-99.957739	21.971434	997	15.3	10	8	---
317	-99.951975	21.976723	998	20	35	8	---
320	-99.866094	21.923849	---	26	---	25.6	---
321	-99.890851	21.908004	995	14.5	---	12.95	---
324	-99.997253	21.956333	994	14.4	25	6.8	---
326	-100.001425	21.964189	998	10	---	9.1	---
327	-100.008172	21.960518	998	76	27	12	28
340	-100.027995	21.972343	1002	35	9	16	23.1
341	-100.028194	21.979033	1002	30	9	17	22.1
342	-100.021723	21.979014	1001	60	20.4	18.1	22
347	-100.039138	21.970137	1005	40	8.3	24	---
377	-100.089606	22.006549	1017	45	35	18	26.5
378	-100.087344	22.009542	1016	45	31.5	18	22
382	-99.861285	22.078124	1024	15	30	13.4	---
384	-99.901223	22.163625	1022	6.5	50	3	---
388	-99.90327	22.156018	1024	11.4	6	5.4	---
389	-100.045283	22.106669	1017	40	36	9.3	---
390	-100.063277	22.104123	1022	60	42	14.55	---
391	-100.069248	22.099555	1030	33	38	14	---
394	-100.053833	22.081925	1015	65	---	12.5	---
395	-100.087321	22.115813	1045	68	17	36.05	---
398	-100.076212	22.150671	1020	43	4	18.5	---
404	-100.018429	22.251074	1029	30	18	3.2	---

no.	W	N	altitude	well depth	yield [l/s]	GWT (static)	GWT (dynamic)
406	-100.007856	22.248237	1030	45	35	3	---
408	-99.987694	22.232465	1027	30	25	1.7	---
409	-99.985329	22.224882	1026	30	20	2.7	---
410	-99.947241	22.247072	---	25	---	2.65	---
412	-99.958036	22.200965	1035	30	---	2.5	---
430	-100.199885	22.192972	1099	6.4	---	4.6	---
431	-100.197228	22.182121	1100	10.2	---	4.2	---
432	-100.197181	22.18835	1098	5.8	---	4.8	---
455	-99.905651	21.993138	1014	6.05	---	4.8	---
456	-99.844248	22.033425	---	22	60	12	---
457	-99.85895	22.030931	1027	52	60	10.4	---
600	-100.031252	21.936697	1001	30	16	6.78	---
603	-100.047189	21.940014	1006	12.48	---	10.28	---
604	-100.048483	21.938678	1006	12.5	---	9.99	---
606	-100.044548	21.92992	1007	12.45	---	10.86	---
607	-100.044192	21.931902	1006	14	15	12.15	---
608	-100.046194	21.933215	1007	13.1	---	11.51	---
609	-100.047084	21.928652	1007	14.96	---	10.1	---
610	-100.050712	21.930992	1007	11.6	---	10.55	---
611	-100.049892	21.929786	1007	13.63	---	10.7	---
612	-100.049786	21.93169	1007	13.43	---	10.63	32.3
614	-100.093427	21.941311	1022	75	16	---	---
616	-100.090589	21.955019	1018	58	8	10.14	---
617	-100.092018	21.95188	1020	50	10	11.64	---
618	-100.086385	21.952965	1016	30	10	8.4	---
619	-100.08467	21.950956	1015	18	8	7	---
620	-100.085122	21.94932	1016	30	25	12.49	---
621	-100.086671	21.94355	1016	30	10	11.5	---
624	-100.092446	21.942817	1022	50	6	10	15
626	-100.078588	21.956941	1014	7	30	4.5	4.7
627	-100.079841	21.95797	1014	7	50	4.7	4.7
628	-100.094937	21.939818	1023	50	---	12.3	---
630	-100.082735	21.941501	1017	25	8	8.7	15.44
633	-100.07581	21.94501	1014	20	8	11.37	---
634	-100.067717	21.949664	1010	42	8	11	15.3
635	-100.057309	21.946038	1007	25	---	10	12.5
636	-100.077157	21.945819	1014	40	---	12.5	---
638	-100.072845	21.947107	1012	25	8	12	---
640	-100.069897	21.944302	1011	18	8	11.86	---
641	-100.068597	21.944888	1011	22	10.2	12	---
642	-100.066667	21.944613	1009	23	10.9	10.8	13.95
643	-100.069915	21.939572	1012	40	8	12.05	14.88
644	-100.0668	21.938844	1012	25.5	8	11	---
645	-100.067319	21.940164	1011	23	8	12	---
647	-100.077996	21.936632	1016	20	15	11.95	16.4
649	-100.085479	21.932311	1019	25	25	10.35	14.2
650	-100.089197	21.931016	1022	30	23.3	10.42	16.98
651	-100.087954	21.931083	1021	30	---	10.39	---
654	-100.062191	21.94187	1009	20	10.9	12	---
655	-100.058537	21.943395	1008	45	15	13	23.25
660	-100.065292	21.92766	1011	50	18	14.71	22
661	-100.062314	21.928315	1009	21	7	14.84	16.82
662	-100.063618	21.931005	1010	60	---	13.15	---
663	-100.0582	21.930535	1008	31	16	14.87	19.49
664	-100.058016	21.92748	1008	25	8	12.49	16
666	-100.065551	21.924935	1011	25	10	12	---
667	-100.067664	21.924863	1012	25	8	13.32	15.18
668	-100.072015	21.924717	1015	20	8	13.29	15
669	-100.074063	21.924241	1017	29	8	14.46	16
670	-100.073595	21.920727	1016	23	10.2	12	---
671	-100.071917	21.920796	1015	28	9	12	---
672	-100.070738	21.921093	1015	22	16.6	11.47	13.68
673	-100.067823	21.921863	1013	50	20	10.96	18
674	-100.064495	21.922163	1010	30	16	10.42	15
675	-100.049574	21.922325	1007	15	9.6	3	8
676	-100.048731	21.918582	1008	25	9.6	7.97	8.82
677	-100.050207	21.916784	1008	35	12	8	---
678	-100.053603	21.91679	1008	18	12.6	8	10.75
679	-100.055744	21.917149	1008	20	8	8	9.37

no.	W	N	altitude	well depth	yield [l/s]	GWT (static)	GWT (dynamic)
681	-100.042375	21.91615	1005	40	---	5.46	---
682	-100.043967	21.914348	1006	10	5	6.26	---
683	-100.04184	21.912978	1005	20	---	5.5	---
684	-100.058226	21.909922	1009	20	12.2	10.14	12.22
689	-100.0349	21.915507	1002	1.55	40	0.72	---
692	-100.03668	21.913014	1002	13	6	3.99	---
696	-100.037514	21.909144	1002	10	6	0.98	---
705	-100.128686	22.005743	1023	40	11.5	18	---
706	-100.162215	22.01507	---	44	21.9	26	---
707	-99.925035	21.996887	1006	30	---	20	---
709	-100.041422	21.958979	1004	30	12.2	5.5	---
711	-100.04034	21.985529	1004	68	14.9	22	33.3
715	-100.074879	21.993014	1012	45	41.6	21	28.2
716	-100.070346	22.000152	1011	50	60.6	18	23.35
717	-100.084102	22.014399	1016	45	21.9	16	20
718	-100.078194	22.015632	1015	40	22.6	16	22
722	-100.114928	22.015161	1023	43	20	23	26.4
732	-100.087246	21.989801	1015	15	19	10.4	13.5
733	-100.085472	21.994179	1014	17	7.6	10	12.3
734	-100.09315	21.975486	1018	23	12.8	12.6	13.5
735	-100.038447	22.002569	1005	40	---	8	---
736	-100.038269	21.950227	1003	45	30	10	---
742	-99.916729	21.856023	---	7	15	4.68	---
743	-99.93101	21.874057	---	10	10	6.4	---
744	-99.974595	21.910318	988	12	2	6.1	---
745	-99.975112	21.907782	988	12	1	6.2	---
746	-99.964776	21.885	988	10	10	4.38	---
747	-99.959548	21.854304	---	5	---	4.4	---
748	-99.959521	21.857995	---	6	---	4.4	---
749	-99.92898	21.814995	---	8	---	5.4	---
764	-99.945513	21.935609	988	9.5	30	8	---
765	-99.948574	21.94163	990	15	10	8	---
766	-99.949146	21.915549	985	40	48	8	12.5
767	-99.944675	21.914382	984	60	40	13.5	---
768	-99.963519	21.923897	986	3.5	---	2	---
769	-99.897136	21.932938	990	250	18	15.5	---
770	-99.90313	21.930188	988	250	35	15.4	---
771	-99.906842	21.932967	988	256	35	10.8	---
772	-99.864579	21.926843	1024	19	---	17.4	---
773	-99.840491	21.917775	---	18.2	---	17.9	---
775	-99.840009	21.945618	---	80	---	39.85	---
776	-99.829335	21.941895	---	80	30	40	---
777	-99.843687	21.953011	---	80	20	42.55	---
779	-99.828078	21.976957	---	120	---	24.8	---
780	-99.820076	21.982009	---	120	---	24.2	---
781	-99.831785	21.980429	---	120	12	22	---
782	-99.843462	21.983232	1041	18.5	2	16.5	---
783	-99.759039	21.965838	---	30.85	---	24.85	---
784	-99.761497	21.969997	---	31	---	29.7	---
785	-99.758071	21.962143	---	8	---	6	---
786	-99.982262	21.964132	996	70	30	9	---
787	-99.982947	21.97244	998	42	14	8.25	---
788	-99.973205	21.977255	998	12.8	22	9.33	---
789	-99.974266	21.968492	997	40	30	9.75	---
791	-99.946412	21.955021	993	40	8	9.3	---
792	-99.942847	21.965853	997	40	33.5	9.2	---
793	-99.935083	21.97252	1005	11.84	16	8.64	---
794	-99.941744	21.980384	1002	13.12	---	9.12	---
795	-99.920605	21.978245	1011	18.8	---	7	---
796	-99.923521	21.987712	1008	13.2	12	7.2	---
798	-99.933494	21.997373	1003	60	---	11	---
799	-99.878814	22.030297	1019	6.15	---	4.65	---
800	-100.040329	21.90432	1003	6	8	2.5	3.74
801	-100.041002	21.903104	1004	8	8	2.67	---
804	-100.040054	21.901496	1003	34	8	3.43	---
811	-100.062168	21.903211	1011	16	8	8.79	---
812	-100.06567	21.900915	1013	24	10	6	8.4
817	-100.049686	21.907559	1007	60	20	7	---
818	-100.047995	21.906854	1007	24	16	6.58	---

no.	W	N	altitude	well depth	yield [l/s]	GWT (static)	GWT (dynamic)
822	-100.057775	21.891663	1013	17	7	9.3	---
823	-100.063433	21.894884	1014	26	8	7.65	12
824	-100.060146	21.895715	1012	18	8	9	13
825	-100.058978	21.897205	1011	23	8	14.36	9
826	-100.0551	21.894654	1009	25	10.9	5	---
827	-100.055873	21.897573	1009	20	8	6.4	12
829	-100.086378	21.922038	1024	20	---	11	---
830	-100.084533	21.917495	1023	31	10	12.49	21
836	-100.088838	21.919137	1026	42	8	8.52	15
841	-100.044182	21.854555	1024	7	---	4.67	---
842	-100.041199	21.854085	1020	14	8	2.84	12
847	-100.042709	21.851783	1024	4.79	---	1.74	20
848	-100.037787	21.844386	1022	6	5	3.51	---
849	-100.037368	21.833772	1028	17.31	---	9.97	---
850	-100.099701	21.960715	1024	40	9	11.78	16.5
851	-100.102944	21.961846	1027	38	8	17	21
852	-100.093795	21.880523	1053	18	8	10.98	14
853	-100.094799	21.881497	1052	13	8	11.6	12.5
854	-100.09275	21.881742	1050	20	10	9.77	4
856	-100.092362	21.880129	1053	15	10	12.44	---
859	-100.092583	21.890567	1037	16.36	8	13.9	---
862	-100.086393	21.893494	1029	18	10	11.72	---
866	-100.092259	21.895818	1029	23	8	10.7	---
867	-100.085494	21.897134	1024	23	16	11.01	13
869	-100.035401	21.830537	1030	9.3	---	8.5	---
870	-100.040378	21.830551	1038	10.98	---	7.39	---
871	-100.041868	21.831017	1042	17.68	---	7.18	---
872	-100.042627	21.924104	1007	27	8	8.77	---
873	-100.044273	21.92727	1007	15	3	10.45	---
874	-100.043573	21.925482	1007	12	24	6.52	---
876	-100.041468	21.919787	1005	5	40	2.58	---
877	-100.007555	21.826763	---	7.5	---	7	---
878	-100.036501	21.930548	1002	45	36	15	18
900	-100.039858	21.89378	1004	11	8	2.14	6
903	-100.049023	21.889737	1009	42	12.2	6.5	10
904	-100.045511	21.893222	1006	12	10	5.45	6.5
906	-100.041379	21.88684	1006	11	4	4.52	---
908	-100.046989	21.884964	1008	7	11	5.52	---
909	-100.045944	21.886298	1007	33	10	4.46	---
910	-100.043463	21.886892	1006	23	9	4.5	8.71
911	-100.052542	21.887059	1014	24	8	9	14
912	-100.05118	21.887645	1012	18	7	8	12.64
914	-100.051363	21.894046	1007	9	8	7.96	---
916	-99.882691	22.044382	1015	50	25	7.3	---
917	-99.880372	22.028457	1018	50	---	7	---
920	-100.009765	21.980594	1000			1	
921	-100.027225	22.054507	1010	---	10	0.5	---
922	-100.028048	22.066736	1011	---	10	0.5	---
923	-100.041655	22.086367	1014	12	10	8.2	---
924	-100.04518	22.098261	1016	12	60	8.45	---
926	-100.042517	22.101616	1017	16	36	8.1	---
927	-100.048298	22.10041	1018	14	30	7.95	---
928	-100.015933	22.10597	1015	12	36	8	---
929	-100.060333	22.100904	1020	14	50	8.46	---
930	-100.081458	22.10103	1036	16	36.8	35	53.5
931	-100.087426	22.10174	1039	14	37.5	35	68
932	-100.076836	22.099272	1034	14	42.9	35	64.4
933	-100.086961	22.097356	1037	14	30	35	69.7
941	-100.10971	22.130936	1055	110	45	28	---
942	-100.131518	22.149556	1063	110	36	32.4	---
943	-100.066813	22.142799	1019	100	81.4	14	20.5
944	-100.162781	22.11325	1070	101	24	32.3	---
945	-100.030658	21.982271	1002	33.5	31.5	33.5	---
947	-100.164275	22.195634	1082	10	30	5.5	---
951	-99.992221	22.234162	1028	22	36	2.46	---
952	-99.977801	22.219529	1028	30	10	1.92	---
976	-100.030543	22.250268	---	25	15	4.11	---
999	-100.044846	22.239929	1038	5.85	8	4.45	---

d) 1986: unpublished data provided by CNA (=Commision Nacional de Agua) (no. = well number according to the report; GWT = groundwater table below well head; altitude in m ASL)

no.	W	N	altitude	GWT
11	-100.036389	21.94966667	1000	16.02
12	-100.040444	21.95769444	1002.7	22.1
17	-100.044528	22.08127778	1017.25	9.62
21	-100.028833	22.10213889	1014.7	10.28
22	-100.045667	22.11558333	1017.85	12.18
24	-100.067944	22.14294444	1019.4	15.8
28	-100.076722	22.12983333	1029.1	28.48
33	-100.072222	21.96711111	1004.6	20.22
35	-100.15325	22.02019444	1034	22.48
36	-100.128583	22.01897222	1019.25	20.22
49	-100.096944	21.93869444	1019.9	15.83
52	-100.054056	21.93858333	1009.55	18.01
59	-99.8923056	21.90416667	983.65	14.33

e) 1996: unpublished data provided by CNA (=Commision Nacional de Agua) (no. = well number according to the report; GWT = groundwater table below well head; altitude in m ASL)

no.	W	N	altitude	GWT
1	-100.087806	21.96483333	1019.8	18.54
2	-100.079194	21.95269444	1007.6	10
4	-100.048139	21.90566667	1008.1	13.03
5	-100.064333	21.902	1016.6	17.7
7	-100.042361	21.88761111	1010.9	5.58
8	-100.050167	21.87994444	1018	5.37
9	-100.041917	21.88538889	1012.8	4.95
10	-100.031083	21.92138889	1000.4	4.14
12	-100.036389	21.94966667	1002.7	25.03
14	-100.043222	21.97036111	1000.25	20
15	-100.055528	21.99436111	1010	27.87
16	-100.009917	21.97408333	993.8	9.53
18	-100.040556	22.089	1016.8	11.24
19	-100.048917	22.09444444	1018.2	12.58
20	-100.043361	22.10597222	1017.57	12.9
21	-100.028833	22.10213889	1014.7	10.2
22	-100.045667	22.11558333	1017.85	13
23	-100.058722	22.13377778	1019.15	14.17
24	-100.067944	22.14294444	1019.4	15.82
25	-100.076167	22.14833333	1028.4	15.9
27	-100.092722	22.13033333	1040.5	37.27
28	-100.076722	22.12983333	1029.1	29.15
29	-100.070333	22.08377778	1023.7	29.96
32	-100.051389	21.94722222	1005.1	21.7
33	-100.072222	21.96711111	1004.6	32.7
34	-100.139944	21.98786111	1060.5	50.45
35	-100.15325	22.02019444	1034	21.56
36	-100.128583	22.01897222	1019.25	20
37	-100.118111	22.01558333	1020	18.43
38	-100.11675	22.00277778	1018.7	22.05
40	-100.083	22.01277778	1020.5	24.18
41	-100.084889	22.0035	1040.2	21.77
44	-100.065611	21.98063889	1004	21
45	-100.094722	21.96405556	1023.9	14.5
46	-100.106028	21.96216667	1032	30.7
47	-100.107028	21.95238889	1034.7	30.7
48	-100.109806	21.94358333	1035.6	26.2
49	-100.096944	21.93869444	1019.9	18.26
53	-99.9572222	21.92841667	982.9	27.39
55	-99.958	21.93633333	980.71	8.7
56	-99.9665833	21.96863889	992.7	9.28
57	-99.9611111	21.965	994.5	12.55
59	-99.8923056	21.90416667	983.65	15
60	-99.8895556	21.91036111	926.25	24.28

f) 1997: unpublished data provided by CNA (=Commision Nacional de Agua) (no. = well number according to the report; GWT = groundwater table below well head)

no.	W	N	altitude	GWT
1	-100.087806	21.96483333	1019.8	18.5
2	-100.079194	21.95269444	1007.6	10.05
3	-100.052694	21.91913889	1012	19.54
4	-100.048139	21.90566667	1008.1	13
5	-100.064333	21.902	1016.6	17.6
6	-100.051139	21.89969444	1010.9	16.9
7	-100.042361	21.88761111	1010.9	5.56
8	-100.050167	21.87994444	1018	5.39
9	-100.041917	21.88538889	1012.8	4.9
10	-100.031083	21.92138889	1000.4	4.11
12	-100.040444	21.95769444	1002.7	18
13	-100.031806	21.97947222	997.8	23.07
14	-100.043222	21.97036111	1000.25	17.6
16	-100.009917	21.97408333	993.8	9.5
17	-100.044528	22.08127778	1017.25	11.15
18	-100.040556	22.089	1016.8	11.24
19	-100.048917	22.09444444	1018.2	12.53
20	-100.043361	22.10597222	1017.57	13.2
21	-100.028833	22.10213889	1014.7	10.25
22	-100.045667	22.11558333	1017.85	13.5
23	-100.058722	22.13377778	1019.15	14.27
24	-100.067944	22.14294444	1019.4	15.86
26	-100.082306	22.13238889	1032.45	31
27	-100.092722	22.13033333	1040.5	37.45
28	-100.076722	22.12983333	1029.1	29.2
29	-100.070333	22.08377778	1023.7	15.86
30	-100.056556	22.08061111	1018.7	27.96
31	-100.075028	22.08694444	1029	28.1
32	-100.051389	21.94722222	1005.1	21.96
33	-100.072222	21.96711111	1004.6	11.88
34	-100.139944	21.98786111	1060.5	50.41
35	-100.15325	22.02019444	1034	21.5
36	-100.128583	22.01897222	1019.25	20
37	-100.118111	22.01558333	1020	19.5
40	-100.083	22.01277778	1020.5	24.7
41	-100.084889	22.0035	1040.2	24.5
42	-100.06825	21.99402778	1008.4	29.2
43	-100.066778	21.97791667	1001.9	28.97
44	-100.065611	21.98063889	1004	19.93
45	-100.094722	21.96405556	1023.9	14.88
46	-100.106028	21.96216667	1032	30.68
47	-100.107028	21.95238889	1034.7	26.76
48	-100.109806	21.94358333	1035.6	18.11
53	-99.9572222	21.92841667	982.9	23.9
54	-99.9540278	21.93413889	986.9	8.7
55	-99.958	21.93633333	980.71	8.7
56	-99.9665833	21.96863889	992.7	9.24
57	-99.9611111	21.965	994.5	12.14
59	-99.8923056	21.90416667	983.65	14.95
60	-99.8895556	21.91036111	926.25	24.2
61	-99.89125	21.89833333	979.53	12.61

g) 1998: unpublished data provided by CNA (=Commision Nacional de Agua) (no. = well number according to the report; GWT = groundwater table below well head; altitude in m ASL)

no.	W	N	altitude	GWT
2	-100.079194	21.95269444	1007.6	10.75
3	-100.052694	21.91913889	1012	18.54
4	-100.048139	21.90566667	1008.1	16.65
5	-100.064333	21.902	1016.6	18.45
6	-100.051139	21.89969444	1010.9	18.63
7	-100.042361	21.88761111	1010.9	8.3

9	-100.041917	21.88538889	1012.8	5.67
10	-100.031083	21.92138889	1000.4	5.1
12	-100.040444	21.95769444	1002.7	26.09
13	-100.031806	21.97947222	997.8	24.13
14	-100.043222	21.97036111	1000.25	22.15
15	-100.055528	21.99436111	1010	28.91
16	-100.009917	21.97408333	993.8	11.4
17	-100.044528	22.08127778	1017.25	10.58
18	-100.040556	22.089	1016.8	11.2
19	-100.048917	22.09444444	1018.2	12.5
20	-100.043361	22.10597222	1017.57	12.7
21	-100.028833	22.10213889	1014.7	10.09
22	-100.045667	22.11558333	1017.85	12.89
23	-100.058722	22.13377778	1019.15	14.15
26	-100.082306	22.13238889	1032.45	31.45
27	-100.092722	22.13033333	1040.5	37.65
28	-100.076722	22.12983333	1029.1	29.65
29	-100.070333	22.08377778	1023.7	28.3
31	-100.075028	22.08694444	1029	32
32	-100.051389	21.94722222	1005.1	22.61
34	-100.139944	21.98786111	1060.5	51.85
35	-100.15325	22.02019444	1034	23.77
36	-100.128583	22.01897222	1019.25	22.25
37	-100.118111	22.01558333	1020	20.85
38	-100.11675	22.00277778	1018.7	10.73
39	-100.088333	22.01125	1040.4	29.2
40	-100.083	22.01277778	1020.5	26.73
41	-100.084889	22.0035	1040.2	26.9
42	-100.06825	21.99402778	1008.4	31.92
43	-100.066778	21.97791667	1001.9	15.47
44	-100.065611	21.98063889	1004	19.37
45	-100.094722	21.96405556	1023.9	16
47	-100.107028	21.95238889	1034.7	31.65
48	-100.109806	21.94358333	1035.6	38.96
49	-100.096944	21.93869444	1019.9	23.81
52	-100.054056	21.93858333	1009.55	31.2
53	-99.9572222	21.92841667	982.9	9
54	-99.9540278	21.93413889	986.9	8.9
55	-99.958	21.93633333	980.71	9.75
56	-99.9665833	21.96863889	992.7	13.5
57	-99.9611111	21.965	994.5	14.65
58	-99.9476111	21.91625	980.7	15.52
59	-99.8923056	21.90416667	983.65	26.13
61	-99.89125	21.89833333	979.53	15.36

h) 1998/99: unpublished data provided by SASAR (= Organismo Operador Paramunicipal de Agua Potable, Alcantarillado y Saneamiento Descentralizado de las Autoridades del Ayuntamiento de Rioverde, S.L.P.) (GWT = groundwater table below well head)

dynamic GWT	P2	P3	P9	P10	P12	P16	P17	PSM	PSD
May 98	42	43.5	41.8	47.4	20	22	70.5	60	
June 98	42	43.9	42	47.6	20.2	22.1	70.6	62.5	
July 98		40	37.22	47.6	20	22.5	71	62.5	
08.08.98		31.8			18	22.3			
10.08.98		40							
Aug. 98		35	32.4	47.6	17	22	73	58	
Sep. 98		35	32.4	47.6	17	21	73.5		
31.10.98		35			16.3	20.5			
Oct. 98	40.7	34.8	36.5	45	16	21	73		
16.11.98		34.8			16	21			
Nov. 98	40.8	34.7		44.9	16	20.8		52	
08.12.98		31				21.3			
24.12.98		29	30			21			
Dec. 98	40.8	29	22.7	44.9	16	21		58	
04.01.99		29.15			16	21			

static GWT	P2	P3	P9	P10	P12	P16	P17	PSM	PSD	PSD old
May 98	36.6	22	13	12	12.3	18	26	25		34
June 98	36.6	22	13	12	12.3	18	26	25		34
July 98	36.6	22	13	12	12.3	18	26	25		34
Aug. 98	24.2	22	13	12	12.3	18	26	25		34
Sep. 98	24.2	22	13	12	12.3	18	26	25		34
Oct. 98	24.2	22	13	12	12.3	18	26	25		34
Nov. 98	24.2	22	13	12	12.3	18	26	25		34
Dec. 98	24.2	22	13	12	12.3	18	26	25		
Jan. 99	24.2	22	13	12	12.3	18	26	25		
Feb. 99	24.2	22	13	12	12.3	18	26	25		
Mar. 99	24.2	22	13	12	12.3	18	26	25		32
Apr .99	24.2	22	13	12	12.3	18	17	25		32
18.06.99									44	
02.07.99								21.6		
05.07.99							26.6			

Jan. 99	40.8	29	22.7	44.9	16	21		58	
04.02.99		33			14	21.5			
Feb. 99	40.8	35	35	44.9	16	21		68.5	
23.03.99		35			16	21			
Mar. 99		35	35		16	21		68.5	
12.04.99		36	37.5		16	21.7			
26.04.99		36	37.5		16	21			53
Apr.99		35	37.5		16	21	41	71	53
04.05.99		38.5							55.5
08.05.99					16	21			57
11.05.99			44.5		16.2	21			55.5
15.05.99			48		16.5	21			56
19.05.99			43			21.3			58
21.05.99			44		17.5	21.15			58.7
26.05.99			42.9		16.2	21.5			57.5
31.05.99		41			16	22.7			57.7
03.06.99		41	40.5		16.1	21.6		73.6	57.15
08.06.99		41	41			21.8		72.7	57
11.06.99		40.9				21.6	79.8	74.1	58
14.06.99		41	41		15.7	21.4		74	
17.06.99						21.6	84		
18.06.99						21.8		72.8	56.3
21.06.99		41	41		15.4	21.4	86.5	72.6	58.3
02.07.99		40							57.7
05.07.99					15.1			72.7	
20.07.99		37.8							59.3
27.07.99		35			13	21	65	72	57.5
06.08.99		35			20.6	21.5		72	57.5
01.09.99		35.7	27.6		20.5	21.55			58.3
11.09.99		35.5	26.5		20	21			57.1
13.09.99		37.7	28.4		20.4	21			58.5
27.09.99		38.5	31.7		20.5	21			59.2
01.10.99								64	
05.10.99			19		20	21.7		67.2	58

07.07.99	26			10.6						
05.10.99		25.5								

i) 1999: field data El Refugio (GWT = groundwater table below well head; altitude in m ASL)

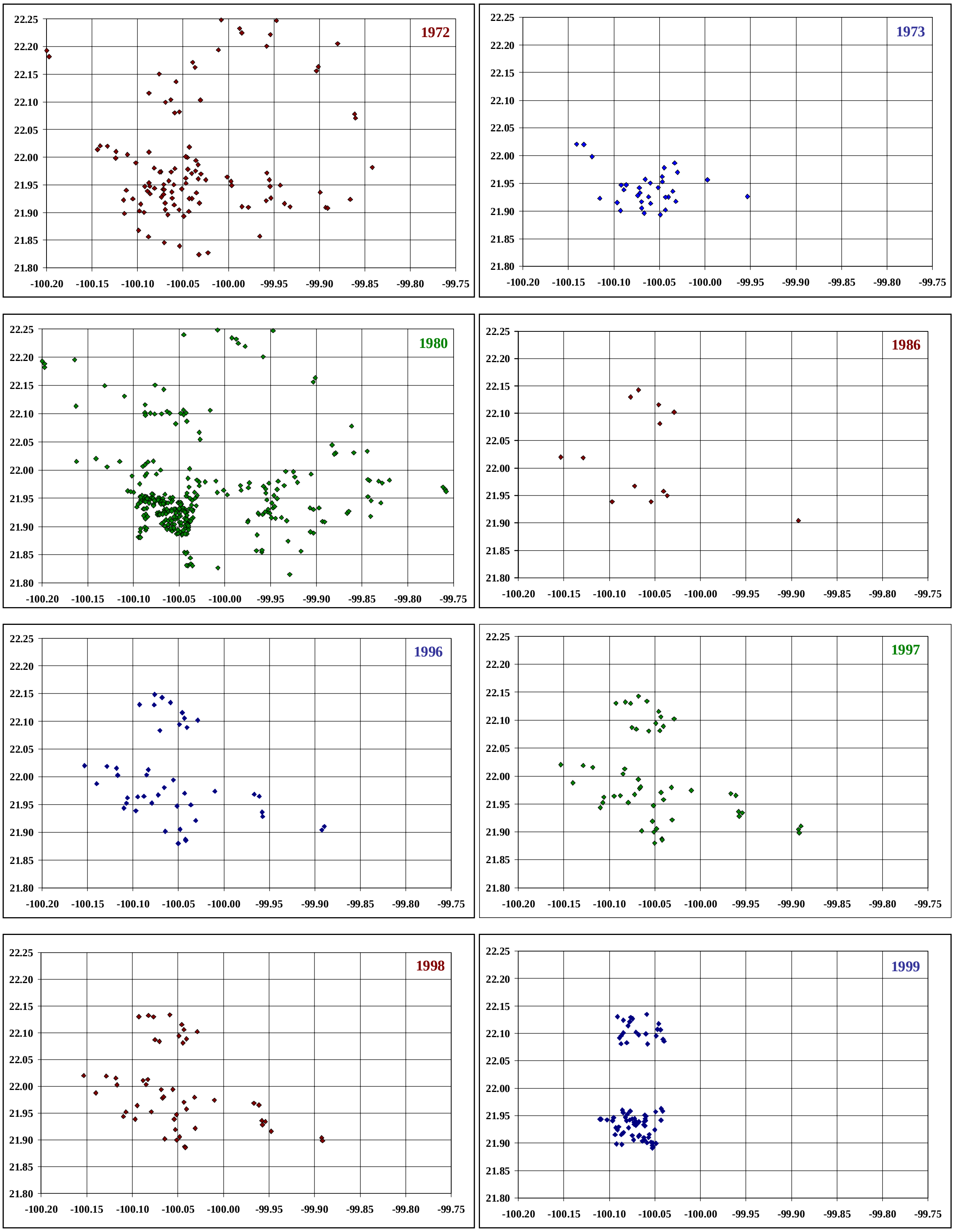
EL REFUGIO	W	N	altitude	total depth	depth of dug well	dynamic GWT	date	static GWT	date
X 1	-100.05282	21.8905	1012	---	13	---	31.07.99	17.1	31.07.99
X 2	-100.05178	21.893083	1008	10	10	---	31.07.99	>10	31.07.99
X 3	-100.05285	21.895133	1008	---	12.5	---	31.07.99	---	31.07.99
X 4	-100.0862	21.897383	1023	---	no dug well	---	31.07.99	12.1	01.08.99
X 5	-100.0922	21.898417	1025	12	12	---	31.07.99	4.5	01.08.99
X 6	-100.0485	21.899433	1006	---	6	---	31.07.99	16.2	31.07.99
X 7	-100.0523	21.90025	1008	---	---	---	31.07.99	---	31.07.99
X 8	-100.05857	21.900467	1011	---	no dug well	---	31.07.99	---	31.07.99
X 9	-100.05402	21.901483	1008	---	15	---	31.07.99	19	31.07.99
X 10	-100.06365	21.903633	1012	---	no dug well	---	31.07.99	21.2	31.07.99
X 11	-100.06142	21.905367	1010	---	7.6	---	31.07.99	23.2	31.07.99
X 12	-100.07337	21.905683	1015	---	---	---	31.07.99	---	31.07.99
X 13	-100.06198	21.909917	1010	48	13	---	31.07.99	---	31.07.99
X 14	-100.05687	21.910067	1009	---	---	---	01.08.99	21.5	31.07.99
X 15	-100.06797	21.911617	1013	50	no dug well	---	01.08.99	---	01.08.99
X 16	-100.07475	21.913783	1017	80	no dug well	---	01.08.99	---	01.08.99
X 17	-100.06702	21.9143	1013	60	no dug well	29.3	01.08.99	---	01.08.99
X 18	-100.09352	21.915217	1028		no dug well	---	01.08.99	11.1	01.08.99
X 19	-100.08687	21.915283	1024	---	no dug well	---	01.08.99	28.8	01.08.99
Sainacio	-100.0561	21.915567	1009	40	no dug well	---	20.07.99	23.8	20.07.99
PSD	-100.08447	21.919167	1023	200	no dug well	57.5	27.07.99	44	18.06.99
PSD (old)	-100.08447	21.919167	1023	180	no dug well	49	12.04.99	36.4	20.07.99
P17	-100.09097	21.924033	1024	170	no dug well	65	27.07.99	26.6	05.07.99
X 20	-100.05008	21.924033	1007	---	no dug well	---	01.08.99	26.3	01.08.99
X 21	-100.0789	21.928	1019	70	no dug well	---	07.07.99	17	07.07.99
P16	-100.09295	21.928183	1027	130	no dug well	21.3	27.07.99	16.4	07.06.99
Santa Amalia	-100.08978	21.929417	1023	200	no dug well	---	07.07.99	22	07.07.99
P3	-100.06093	21.93155	1009	60	no dug well	37.8	20.07.99	22	01.04.99
P12	-100.07082	21.932383	1015	150	no dug well	13	27.07.99	12.3	01.04.99

Ramon	-100.06223	21.933667	1010	---	no dug well	---	07.07.99	28	07.07.99
X 22	-100.07252	21.9339	1016	105	no dug well	---	07.07.99	27	07.07.99
Guayabas	-100.07263	21.937733	1015	135	no dug well	---	07.07.99	---	07.07.99
Guayabas old	-100.07263	21.937733	1015	60	no dug well	---	07.07.99	16.5	07.07.99
X 23	-100.06778	21.9378	1012	---	no dug well	---	27.07.99	21.2	27.07.99
X 24	-100.06808	21.937817	1012	---	no dug well	---	27.07.99	---	27.07.99
X 25	-100.0706	21.938033	1013	---	no dug well	---	27.07.99	---	27.07.99
X 26	-100.07018	21.93845	1013	60	no dug well	---	27.07.99	18.3	27.07.99
X 27	-100.07018	21.93845	1013	100	no dug well	---	27.07.99	18.5	27.07.99
P2	-100.06167	21.939067	1010	57	no dug well	40.8	07.07.99	26	07.07.99
X 28	-100.0673	21.939217	1011	---	no dug well	---	27.07.99	21.8	27.07.99
P9	-100.08098	21.94085	1016	70	no dug well	28	27.07.99	13	01.04.99
X 29	-100.09632	21.940967	1024	---	no dug well	---	01.08.99	---	01.08.99
X 30	-100.06	21.941033	1009	---	12	---	27.07.99	23.1	27.07.99
Dona Matilde	-100.04323	21.9418	1004	---	13	---	28.07.99	32	28.07.99
X 31	-100.07765	21.942117	1016	---	no dug well	---	27.07.99	15	27.07.99
PSM	-100.1026	21.942417	1030	172	no dug well	72	27.07.99	21.6	02.07.99
X 32	-100.11018	21.943517	1035	---	no dug well	---	01.08.99	32.2	01.08.99
X 33	-100.10908	21.94355	1034	---	no dug well	---	01.08.99	33	01.08.99
Huerta los Pin.	-100.06055	21.94395	1008	---	no dug well	---	07.07.99	28	07.07.99
X 34	-100.07497	21.943967	1014	---	no dug well	---	07.07.99	18.4	07.07.99
P10	-100.07213	21.944433	1013	65	no dug well	44.9	02.99	10.6	07.07.99
X 35	-100.09537	21.94615	1025	---	no dug well	---	01.08.99	21.2	01.08.99
X 36	-100.08238	21.947267	1016	---	no dug well	---	01.08.99	14	01.08.99
X 37	-100.08238	21.947267	1016	11.7	11.7	---	01.08.99	>11.7	01.08.99
Chilera	-100.0599	21.949017	1006	---	no dug well	45.7	07.07.99	---	07.07.99
El Peloteado	-100.06107	21.951233	1006	38	no dug well	---	07.07.99	21.7	07.07.99
El Encinito I	-100.07997	21.953017	1014	40	no dug well	---	07.07.99	10.4	07.07.99
El Encinito II	-100.08477	21.955583	1015	---	no dug well	---	07.07.99	---	07.07.99
X 38	-100.04918	21.9571	1005	---	no dug well	---	01.08.99	24.9	01.08.99
X 39	-100.0414	21.958283	1004	---	no dug well	---	01.08.99	22.8	01.08.99
X 40	-100.08562	21.95985	1015	---	no dug well	---	01.08.99	---	01.08.99
X 41	-100.04302	21.962667	1005	175	no dug well	---	01.08.99	24.6	01.08.99
fault well	-100.07708	21.95805	1013	---	---	---	01.08.99	7.5	03.08.99

k) 1999: field data Pastora (GWT = groundwater table below well head; altitude in m ASL)

PASTORA	W	N	altitude	total depth	dynamic GWT	date	static GWT	date
El Otomite	-100.058	22.08065	1016	---	---	06.08.99	---	06.08.99
Y 1	-100.087133	22.08113333	1031	---	---	06.08.99	58.8	06.08.99
Y 2	-100.0808	22.08291667	1028	---	---	06.08.99	---	06.08.99
Y 3	-100.039933	22.08566667	1014	---	---	06.08.99	11.7	06.08.99
Y 4	-100.04105	22.08933333	1014	---	---	06.08.99	11.9	06.08.99
Y 5	-100.088667	22.09175	1036	---	---	06.08.99	59	06.08.99
El Trebol I	-100.048467	22.09533333	1016	---	---	06.08.99	13.1	06.08.99
Y 6	-100.087033	22.09593333	1037	---	---	06.08.99	>50	06.08.99
Y 7	-100.067633	22.09733333	1028	---	---	06.08.99	---	06.08.99
El Trebol II	-100.059717	22.09906667	1020	---	---	06.08.99	16.7	06.08.99
Rancho #13	-100.084667	22.10108333	1038	150	33	06.08.99	---	06.08.99
Y 8	-100.070817	22.10231667	1031	---	---	06.08.99	31.3	06.08.99
Piedras Negras 1	-100.043817	22.10663333	1017	---	---	06.08.99	13.4	06.08.99
Piedras Negras 2	-100.047167	22.10745	1018	---	---	06.08.99	---	06.08.99
La Gloria	-100.079433	22.11371667	1038	---	37		36	
La Cabana	-100.045783	22.11743333	1016	---	60	23.07.99	15.8	23.07.99
San Isidro	-100.0775	22.1214	1035	65	41		38	
Santo Domingo	-100.084633	22.12421667	1039	50	36		---	
Vergel I	-100.07435	22.12676667	1032	80	---	23.07.99	---	23.07.99
Vergel II	-100.076433	22.12938333	1031	80	32		31.85	23.07.99
Chamizal	-100.09105	22.1305	1041	---	---	23.07.99	40.1	23.07.99
Pastora	-100.058817	22.13478333	1018	30	---	23.07.99	16.9	23.07.99

App.No.23.: Distribution of the groundwater table data (1972-1999, App.No.22)



App.No.24.: Summarized results of all chemical determinations for the selected wells and springs

(green: uncertain values due to determination problems)

(a) El Refugio area - June / July 1999

name	**P3**	**P9**	**P12**	**P16**	**P17**	**PSD**	**Chilera**	**El Peloteado**	**El Encinito I**	**El Encinito II**	**Doña Matilde**	**Huerta los Pinos**	**Las Guayabas**
longitude latitude	100°03.656' 21°55.893'	100°04.859' 21°56.451'	100°04.249' 21°55.943'	100°05.577' 21°55.691'	100°05.458' 21°55.442'	100°05.068' 21°55.150'	100°03.594' 21°56.941'	100°03.664' 21°57.074'	100°04.798' 21°57.181'	100°05.086' 21°57.335'	100°02.594' 21°56.508'	100°03.633' 21°56.637'	100°04.358' 21°56.264'
GW table (m)	41	41	15.57	21.4	84	56.3	45.7	18.7	10.4	n.d.	n.d.	28	n.d.
sampling date	15.06.99	18.06.99	14.06.99	15.06.99	15.06.99	19.06.99	19.06.99	16.06.99	17.06.99	17.06.99	16.06.99	18.06.99	18.06.99
sampling time	16:30	15:00	11:15	11:00	09:00	10:30	13:00	13:30	16:00	10:00	11:30	08:00	13:00
field													
Temp (°C)	26.3	24.6	28.9	28.5	26.1	25.9	25	27.6	28.9	25.7	24.1	25	28.4
pH	7.05	7.17	6.74	7.04	7.06	7.16	6.93	6.85	6.73	7.05	6.92	7.15	6.76
conductivity (µS/cm)	624	449	1589	604	386	437	1242	1325	1580	774	1796	911	1619
TDS (mg/L)	583	n.d.	3820	534	349	n.d.	n.d.	1150	n.d.	n.d.	1540	n.d.	n.d.
EH (mV)	185	235	204	97	146	89	126	98	119	256	137	115	25
$EH_{corrected}$ (mV)	390	442	407	301	352	295	332	302	322	462	344	321	229
O_2 (%)	39	n.d.	9	0	5	n.d.	n.d.	61	n.d.	n.d.	34	n.d.	n.d.
O_2 (mg/L)	4.3	n.d.	0.8	0	5.9	n.d.	n.d.	4.9	n.d.	n.d.	3.4	n.d.	n.d.
Fe (II) (mg/L)	0.04	0.02	0.63	0.04	0.02	0.02	0.2	0.25	0.13	0.02	0.37	0.06	0.58
Fe (ges) (mg/L)	0.07	0.14	0.88	0.08	0.05	0.04	0.06	0.03	0.01	0.02	0.04	0.02	0.28
Fe (III) (mg/L)	0.03	0.12	0.25	0.04	0.03	0.02	-0.14	-0.22	-0.12	0	-0.33	-0.04	-0.3
$N-NO_3$ (mg/L)	7.7	9.3	0.14	0.21	3.3	3.4	4.7	4.4	2.2	2.6	4.5	4.3	0.1
NO_3 (mg/L)	34.11	41.20	0.62	0.93	14.62	15.06	20.82	19.49	9.75	11.52	19.94	19.05	0.44
$N-NO_2$ (mg/L)	0.046	0.048	0.04	0.04	0.033	0.015	0.014	0.024	0.035	0.038	0.101	0.019	0.041
NO_2 (mg/L)	0.15	0.16	0.13	0.13	0.11	0.05	0.05	0.08	0.12	0.13	0.33	0.06	0.14
$N-NH_3$ (mg/L)	0.01	0.1	1.18	0.02	0	0.05	0.1	0.38	0.27	0.06	1.52	0.01	0.6
NH_4^+ (mg/L)	0.013	0.129	1.522	0.026	0	0.065	0.129	0.490	0.348	0.077	1.961	0.013	0.774
PO_4 (mg/L)	0.21	0.51	0.61	0.25	0.22	0.28	0.16	0.39	0.18	0.28	0.22	0.34	0.18
$PO_{4corr.}$ (mg/L)	0.2	0.5	0.6	0.24	0.21	0.27	0.15	0.38	0.17	0.27	0.21	0.33	0.17
p-value (digits)	39	75	215	48	63	83	98	124	201	76	143	212	258
CO_2 (mmol/L)	0.0975	0.1875	0.5375	0.12	0.1575	0.2075	0.245	0.31	0.5025	0.19	0.3575	0.53	0.645
CO_2 (mg/L)	4.29	8.25	23.65	5.28	6.93	9.13	10.78	13.64	22.11	8.36	15.73	23.32	28.38
m-value (digits)	1515	1420	1861	1626	1440	1578	1607	1610	1905	1836	1723	1598	1918
HCO_3(mmol/L)	3.7875	3.55	4.6525	4.065	3.6	3.945	4.0175	4.025	4.7625	4.59	4.3075	3.995	4.795
HCO_3 (mg/L)	231.04	216.55	283.80	247.97	219.60	240.65	245.07	245.53	290.51	279.99	262.76	243.70	292.50
laboratory													
K (mg/L)	2.08	6.24	3.21	2.87	3.57	3.4	4.76	4.29	3.59	3.42	3.66	5.12	3.3
Na (mg/L)	11.48	28.58	18.72	14.6	18.78	24.6	37.88	32.51	23.26	16.62	33.75	36.89	19.68
Mg (mg/L)	18.69	7.84	62.11	20.5	8.44	9.04	35.58	28.34	56.08	24.72	56.08	23.52	60.91
Ca (mg/L)	103.43	62.65	303.33	72.6	59.67	65.63	218.79	247.64	301.34	125.31	301.34	142.21	308.3
Li (mg/L)	0.01	0.01	0.06	0.01	0.01	0.01	0.05	0.05	0.06	0.02	0.04	0.04	0.06
Cl (mg/L)	9	11.5	6	4	5	9.4	18	24	10	9.8	20	10	5
SO_4 (mg/L)	98.582	13.964	779.1	69.96	7.7762	16.935	514.13	487.28	755.65	194.2	911.3	279.9	785.15
SiO_2 (mg/L)	27.37	53.93	21.59	32.16	51.55	52.25	40.97	49.97	25.34	29.68	35.02	47.75	21.9
F (mg/L)	0.39	0.453	1.3	0.755	0.255	0.24	0.9	0.99	1.2	0.86	0.442	0.48	1.29
NO_3 (mg/L)	43.41	35.42	1.45	4.52	10.67	16.52	29.06	36.01	10.66	20.38	41.72	26.25	1.49
As (µg/L)	8.541	6.587	4.580	6.993	3.806	3.585	8.004	9.973	6.445	8.151	10.332	8.688	3.329
isotopes													
T.U. (27.07.99)	2.57	0.92	-0.16	-0.11	1.01	0.78	0.26	1.97	n.d.	n.d.	n.d.	n.d.	n.d.
sig2	0.66	0.6	0.55	0.57	0.59	0.59	0.53	0.42	n.d.	n.d.	n.d.	n.d.	n.d.
d^2H ‰ (20.07.)	-56.7	-58.3	-62.9	-56.2	-56.8	-51.9	-59.4	-56.9	-59.8	n.d.	n.d.	n.d.	n.d.
$d^{18}O$ ‰ (20.07.)	-7.66	-7.79	-9.02	-8.48	-8.47	-7.38	-8.19	-7.56	-8.25	n.d.	n.d.	n.d.	n.d.
d_{excess}	4.57	4.02	9.21	11.64	10.94	7.11	6.17	3.56	6.18	n.d.	n.d.	n.d.	n.d.
$d^{18}Ocorr$	-9.21	-9.50	-9.24	-8.01	-8.20	-8.21	-9.28	-9.40	-9.34	n.d.	n.d.	n.d.	n.d.

name	P3	P9	P12	P16	P17	PSD	Chilera	El Peloteado	El Encinito I	El Encinito II	Doña Matilde	Huerta los Pinos	Las Guayabas
ICP-MS (20.7.1999) [µg/L]													
Li 7	11.21519	12.81985	30.07182	12.99761	14.62116	14.05321	30.92303	22.95419	22.49804	n.d.	n.d.	n.d.	n.d.
B 11	14.68573	27.34692	29.99648	15.25695	39.39083	26.34591	31.09426	22.93638	27.46416	n.d.	n.d.	n.d.	n.d.
Al 27	231.2609	266.4893	856.0066	164.6655	79.63498	203.3887	154.0707	711.5335	704.4298	n.d.	n.d.	n.d.	n.d.
Ca 44	92533.86	57976.39	242213.7	76461.14	79304.05	61136.04	203653.2	258048.2	202222.8	n.d.	n.d.	n.d.	n.d.
Sc 45	21.50465	36.49314	32.25948	15.5747	15.52837	35.04601	38.72082	52.01189	45.23755	n.d.	n.d.	n.d.	n.d.
Cr 52	0.97815	0.88961	1.76661	1.57549	0.88535	1.15033	1.57465	1.38381	1.33962	n.d.	n.d.	n.d.	n.d.
Fe 54	129.6450	159.9339	668.4789	680.4803	191.9570	483.7935	219.9818	259.0491	250.6278	n.d.	n.d.	n.d.	n.d.
Mn 55	2.3459	2.14893	1378.289	4.826	0.15663	2.94002	1.7643	6.71347	8.72706	n.d.	n.d.	n.d.	n.d.
Co 59	0.84409	0.92642	10.80388	1.0153	0.43309	1.22192	2.7873	3.95108	2.7229	n.d.	n.d.	n.d.	n.d.
Ni 60	13.20862	10.50312	26.35651	12.45696	11.26519	12.50436	24.8317	23.82943	18.78277	n.d.	n.d.	n.d.	n.d.
Cu 63	13.39389	14.52665	77.5146	11.93564	9.59506	17.48836	24.84302	27.01653	24.39647	n.d.	n.d.	n.d.	n.d.
Zn 66	57.91301	115.7267	167.6570	89.50693	29.23393	48.82725	43.2206	26.89209	21.27016	n.d.	n.d.	n.d.	n.d.
As 75	7.97059	5.30453	9.89443	10.88931	6.77822	5.80983	15.92403	23.52673	15.12001	n.d.	n.d.	n.d.	n.d.
Se 82	8.88581	5.96853	25.66487	14.28418	8.66471	11.78009	22.78322	29.46333	25.93662	n.d.	n.d.	n.d.	n.d.
Sr 88	565.3229	354.6525	2979.423	497.6875	460.2641	310.4261	3071.694	2963.446	1840.727	n.d.	n.d.	n.d.	n.d.
Y 89	0.04993	1.38933	0.5142	0.09797	0.06645	0.16155	0.21585	0.34103	0.39019	n.d.	n.d.	n.d.	n.d.
Cd 114	0.13093	0.12554	0.47142	0.37589	0.1833	0.19308	0.29735	0.37182	0.33983	n.d.	n.d.	n.d.	n.d.
Sb 121	0.38506	0.17009	0.53037	0.2601	0.09406	0.31632	0.60865	0.2792	0.11868	n.d.	n.d.	n.d.	n.d.
Ba 138	141.5032	169.2499	64.65887	79.01651	126.9929	157.7843	32.12981	40.71648	58.96763	n.d.	n.d.	n.d.	n.d.
La 139	0.08873	5.34384	1.02064	0.03785	0.02411	0.23671	0.09802	0.42946	0.45883	n.d.	n.d.	n.d.	n.d.
Ce 140	0.84729	3.23945	19.06562	0.29113	0.0577	3.02053	0.19642	14.19727	12.84287	n.d.	n.d.	n.d.	n.d.
Pr 141	0.07474	1.20015	0.17272	0.00611	-0.00158	0.01294	-0.0058	0.0004	0.10522	n.d.	n.d.	n.d.	n.d.
Nd 146	0.17568	3.83389	0.52525	0.14604	0.13098	0.15467	0.07975	0.32247	0.41066	n.d.	n.d.	n.d.	n.d.
Sm 147	0.87838	1.54481	0.99442	0.74388	0.87926	0.85487	0.69999	0.89983	0.79096	n.d.	n.d.	n.d.	n.d.
Eu 151	0.04935	0.15425	0.03025	0.0872	0.02454	0.02957	0.03924	0.02236	0.05996	n.d.	n.d.	n.d.	n.d.
Gd 157	0.1337	0.7869	0.56573	0.01956	0.11442	0.2277	0.09473	0.09542	0.11216	n.d.	n.d.	n.d.	n.d.
Tb 159	0.01995	0.07188	0.00395	0.00979	0.01371	0.01401	0.01604	0.03215	0.02545	n.d.	n.d.	n.d.	n.d.
Dy 162	0.01263	0.41869	0.06572	0.01224	0.03515	0.08101	0.04965	0.033	0.14094	n.d.	n.d.	n.d.	n.d.
Ho 165	0.00377	0.04689	0.02275	0.00325	0.03369	0.00707	0.00827	0.00464	-0.0036	n.d.	n.d.	n.d.	n.d.
Er 166	0.01102	0.12634	0.06961	0.01028	0.02342	0.02864	0.0493	0.03894	0.01543	n.d.	n.d.	n.d.	n.d.
Tm 169	0.00104	0.01328	0.00648	0.00701	0.03714	0.0108	0.00661	0.01465	0.00214	n.d.	n.d.	n.d.	n.d.
Yb 174	0.00003	0.08312	0.03589	-0.00047	0.05924	0.00899	0.00435	0.07978	0.01302	n.d.	n.d.	n.d.	n.d.
Lu 175	-0.00266	0.0373	0.01492	0.00257	0.02387	0.00571	0.0083	0.01524	-0.00539	n.d.	n.d.	n.d.	n.d.
Tl 203	0.06141	0.00422	0.03824	0.16912	0.12369	0.03964	0.22339	0.06767	0.15493	n.d.	n.d.	n.d.	n.d.
Pb 208	5.42431	7.39621	8.60602	12.1524	6.34251	7.47033	9.13147	7.69041	6.51358	n.d.	n.d.	n.d.	n.d.
Th 232	0.03028	0.082555	0.09858	0.058635	0.41904	0.11122	0.03125	0.130755	0.156405	n.d.	n.d.	n.d.	n.d.
U 238	2.92456	2.66694	2.74659	2.250705	2.312085	3.94526	6.774285	1357.8	1529.3	n.d.	n.d.	n.d.	n.d.
U 238 (2nd measuring)								678.9007	764.6338				
U 238 (3rd measuring)								407.8	476.2				

(b) Pastora area - July 1999

name	La Cabana	Pastora	Chamizal	San Isidro	Sto. Domingo	Vergel I	Vergel II	Rancho #13	La Gloria
longitude	100°02.747'	100°03.529'	100°05.463'	100°04.650'	100°05.078'	100°04.461'	100°04.586'	100°05.080'	100°04.766'
latitude	22°07.046'	22°08.087'	22°07.830'	22°07.284'	22°07.453'	22°07.606'	22°07.763'	22°06.065'	22°06.823'
GW table (m)	15.8	16.9	40.1	40	36	n.d.	31.85	33	37
sampling date	01.07.99	30.06.99	03.07.99	02.07.99	02.07.99	02.07.99	30.06.99	01.07.99	01.07.99
sampling time	11:00	12:00	11:30	09:00	10:30	14:00	16:00	12:00	13:30
field									
Temp (°C)	24.8	24.7	24.9	24.2	24.7	24.8	26.5	26.9	25
pH	7.19	7.14	7.02	7.07	7	6.99	6.86	6.99	7.04
conductivity (µS(/cm)	3590	3180	2330	3060	2870	3540	2900	3670	3030
EH (mV)	-45	145	268	149	108	143	224	186	115
$EH_{corrected}$ (mV)	162	352	474	356	315	350	429	391	321
O_2 (mg/L)	2.75	5.96	4.75	6.13	4.9	5.47	5.58	7.3	7.1
$N\text{-}NO_2$ (mg/L)	0.051	0.025	0.014	0.043	0.016	0.032	0.019	0.019	0.018
NO_2 (mg/L)	0.17	0.08	0.05	0.14	0.05	0.11	0.06	0.06	0.06
PO_4 (mg/L)	0.14	0.32	0.34	0.12	0.13	0.16	0.33	0.99	0.21
$PO_{4corrected}$ (mg/L)	0.13	0.31	0.33	0.11	0.12	0.15	0.32	0.98	0.2
p-value (digits)	148	153	101	128	105	110	148	159	109

name	La Cabana	Pastora	Chamizal	San Isidro	Sto. Domingo	Vergel I	Vergel II	Rancho #13	La Gloria
CO_2 (mmol/L)	0.37	0.3825	0.2525	0.32	0.2625	0.275	0.37	0.3975	0.2725
CO_2 (mg/L)	16.28	16.83	11.11	14.08	11.55	12.1	16.28	17.49	11.99
m-value (digits)	1456	1280	1263	1287	1147	1227	1347	1443	1203
HCO_3 (mmol/L)	3.64	3.2	3.1575	3.2175	2.8675	3.0675	3.3675	3.6075	3.0075
HCO_3 (mg/L)	222.04	195.20	192.61	196.27	174.92	187.12	205.42	220.06	183.46
laboratory									
K (mg/L)	11.79	11.1	11.79	11.15	14.56	16.01	11.15	13.93	12.39
Na (mg/L)	94.29	66.94	51.57	104.29	89.18	251.43	83.8	135.61	75.27
Mg (mg/L)	275.5	180.6	106.53	113.26	124.89	162.24	275.5	153.05	162.24
Ca (mg/L)	575.46	545.17	430.1	600.7	520.94	535.07	575.46	666.32	519.93
Cl (mg/L)	18	12	56	34	17	34	16.5	80	44
SO_4 (mg/L)	2462.7	2140.1	1406.3	1798.2	1712.3	2022	1797.1	1862.3	1676.8
SiO_2 (mg/L)	33.7	35.8	32.1	35.35	24.35	34.1	34.5	41.55	41.15
F (mg/L)	1.77	1.88	2.05	1.72	2.27	1.77	1.86	2.04	1.31
NO_3 (mg/L)	0.95	14.93	8.24	18.69	12.75	24.67	13.24	17.85	22.06
As (µg/L)	8.59	9.02	26.54	9.82	23.82	7.84	4.15	42.76	4.61
B (mg/L)	0.2	0.55	1.99	1.06	0.85	2.53	1.62	2.48	1.41
isotopes									
T.U. (23.07.1999)	0.68	0.81	n.d.	0.6	0.16	0.69	0.48	0.44	n.d.
sig2	0.58	0.58	n.d.	0.56	0.59	0.58	0.55	0.57	n.d.
d^2H ‰ (23.07.1999)	-55.6	-54.9	n.d.	-55.5	-53.0	-55.5	-56.0	-53.3	n.d.
$d^{18}O$ ‰ (23.07.1999)	-7.39	-7.54	n.d.	-7.58	-7.16	-7.61	-7.66	-7.05	n.d.
d_{excess}	3.48	5.39	n.d.	5.17	4.25	5.33	5.29	3.11	n.d.
$d^{18}O_{corr}$	-9.25	-8.86	n.d.	-8.96	-8.80	-8.94	-9.00	-9.02	n.d.
ICP-MS (23.7.1999) [µg/L]									
Li 7	140.4045	83.33618	n.d.	86.29745	103.68108	90.41754	92.1317	117.94036	n.d.
B 11	352.03159	239.80784	n.d.	256.87671	165.95647	352.07048	307.3613	301.68513	n.d.
Al 27	299.96421	190.36753	n.d.	138.82652	897.45477	192.05764	1127.2684	734.22417	n.d.
Ca 44	505803.13	487267.25	n.d.	462641.05	480135.0599	449968.89	486265.85	611087.74	n.d.
Sc 45	33.77935	33.73006	n.d.	35.16545	38.58636	34.18977	39.33021	42.85253	n.d.
Cr 52	2.29773	3.8561	n.d.	1.35806	2.20015	1.95713	2.44844	2.37244	n.d.
Fe 54	596.15268	293.74823	n.d.	1154.7461	551.27839	171.00355	293.80508	161.8512	n.d.
Mn 55	35.22648	2.28688	n.d.	56.05654	23.54116	1.62936	10.25805	3.52492	n.d.
Co 59	4.0071	4.03803	n.d.	8.78149	5.04861	2.68489	3.8388	3.37242	n.d.
Ni 60	38.54243	42.92809	n.d.	58.91796	41.29632	35.04113	36.402	40.20191	n.d.
Cu 63	15.73477	16.82436	n.d.	18.1867	37.28066	14.45868	15.42378	12.00971	n.d.
Zn 66	81.92721	17.20136	n.d.	53.02599	68.95318	10.31653	49.96253	14.65219	n.d.
As 75	17.9726	12.47886	n.d.	16.42373	19.74697	17.01566	16.59425	45.39552	n.d.
Se 82	55.32348	32.20641	n.d.	49.54446	38.63367	45.32232	48.58337	68.27681	n.d.
Sr 88	11658.803	9146.3616	n.d.	9015.4192	10294.14584	8568.7336	9018.5925	11819.278	n.d.
Y 89	0.2472	0.24008	n.d.	0.32483	9.61903	0.29559	0.30473	0.24395	n.d.
Cd 114	0.17196	0.38197	n.d.	0.49707	0.25546	0.05704	0.35835	0.17674	n.d.
Sb 121	0.53638	0.40133	n.d.	0.33963	0.36648	0.414	0.17519	0.80698	n.d.
Ba 138	17.96979	12.8547	n.d.	21.9128	25.31182	20.55467	34.91352	25.65881	n.d.
La 139	0.07016	0.12479	n.d.	0.11899	6.77529	0.00652	0.85872	0.48149	n.d.
Ce 140	0.57656	0.20346	n.d.	0.31499	9.02584	0.2564	26.51754	14.65474	n.d.
Pr 141	0.03533	-0.00242	n.d.	-0.00479	2.1057	0.0229	0.21268	0.14867	n.d.
Nd 146	0.12115	0.02627	n.d.	0.05266	7.56473	0.05729	0.2778	0.35459	n.d.
Sm 147	0.84486	0.74053	n.d.	0.94068	2.94771	0.77463	1.01711	0.73932	n.d.
Eu 151	0.0614	0.04498	n.d.	0.04977	0.60311	0.01584	0.0512	0.01607	n.d.
Gd 157	0.13546	0.173	n.d.	0.18657	2.07411	0.07614	0.48921	0.16939	n.d.
Tb 159	0.00104	0.01032	n.d.	0.00876	0.37052	0.00547	0.03025	0.04908	n.d.
Dy 162	0.05342	0.0366	n.d.	0.06871	2.37013	0.05392	0.05255	0.09116	n.d.
Ho 165	0.00994	0.01492	n.d.	0.01671	0.42952	0.0142	0.01349	0.02665	n.d.
Er 166	0.04266	0.03282	n.d.	-0.00344	1.05361	-0.0029	0.07543	0.03205	n.d.
Tm 169	0.00751	0.02561	n.d.	-0.00119	0.15096	-0.00099	0.0073	0.01642	n.d.
Yb 174	0.10954	0.03057	n.d.	0.0272	0.70867	0.01778	0.0622	0.01807	n.d.
Lu 175	0.00564	-0.00159	n.d.	0.00522	0.1293	0.01688	0.00547	0.00584	n.d.
Tl 203	0.25671	0.0768	n.d.	0.2168	0.94413	0.27461	0.22227	0.96019	n.d.
Pb 208	4.56229	16.90473	n.d.	5.42603	7.14797	3.58215	4.95443	6.15166	n.d.
Th 232	0.058505	0.01841	n.d.	0.024245	0.10685	0.022005	0.14343	0.18206	n.d.
U 238	4.26988	3.79885	n.d.	5.358345	169.0	13.30907	1573.6	1986.74	n.d.
U 238 (2nd measuring)					84.48244		786.79086	993.37016	
U 238 (3rd measuring)					51.6		527.6	657.9	

(c) Springs - July 1999

name	Media Luna (Crater A)	Media Luna (Crater B/C)	Media Luna (Crater D)	Media Luna (Crater E)	Media Luna (Crater F)	Media Luna (Cave)	Anteojitos	Ojo de Agua de Solano
longitude	100°01.391´						100°00.344´	100°05.033´
latitude	21°51.581´						21°52.713´	21°59.014´
depth (m)	16	18	9	14	36	3	12	1
sampling date	21.07.99	21.07.99	21.07.99	21.07.99	21.07.99	21.07.99	27.07.99	30.07.99
field								
Temp (°C)	29	29	29	29	33	28	30.2	29.4
pH	7.12	7.03	7.13	7.14	7.03	7.04	7.12	6.84
conductivity (µS/cm)	1802	1782	1778	1794	1813	1763	1825	1646
EH (mV)	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
O_2 (mg/L)	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
NO_2 (mg/L)	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
PO_4 (mg/L)	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.12	0.03
p-value (digits)	352	244	246	214	287	280	145	234
CO_2 (mmol/L)	0.88	0.61	0.615	0.535	0.7175	0.7	0.3625	0.585
CO_2 (mg/L)	38.72	26.84	27.06	23.54	31.57	30.8	15.95	25.74
m-value (digits)	1956	1997	1983	1972	2017	1962	1954	1989
HCO_3 (mmol/L)	4.89	4.9925	4.9575	4.93	5.0425	4.905	4.885	4.9725
HCO_3 (mg/L)	298.29	304.54	302.41	300.73	307.59	299.21	297.99	303.32
laboratory								
K (mg/L)	3.33	3.4	3.32	3.38	3.5	3.5	3.6	3.53
Na (mg/L)	18.41	18.25	18.9	19.32	19.51	19.18	19.83	18.82
Mg (mg/L)	65.96	64.18	68.93	65.96	66.55	66.55	65.36	58.23
Ca (mg/L)	351.8	352.78	344.94	350.82	360.62	345.92	371.4	320.44
Cl (mg/L)	9	9	8.5	10	11.5	10	10.5	7
SO_4 (mg/L)	906.15	941.3	944	971.15	981.05	955.6	1022.8	803.55
SiO_2 (mg/L)	20.74	20.49	20.68	20.85	20.95	20.96	20.16	22.18
F (mg/L)	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
NO_3 (mg/L)	1.35	1.6	1.34	1.27	1.02	1.91	1.15	1.92
As (µg/L)	8.20	8.66	8.57	8.55	8.57	8.25	9.05	8.29
isotopes								
T.U. (21.07.99)	n.d.	0.8	n.d.	n.d.	1.5	1.6	0.7	1.1
sig2	n.d.	0.58	n.d.	n.d.	0.7	0.6	0.6	0.6
d^2H ‰ (21.07.)	n.d.	-65.9	n.d.	n.d.	-66.0	-66.6	-65.9	-66.0
$d^{18}O$ ‰ (21.07.)	n.d.	-8.83	n.d.	n.d.	-9.40	-9.28	-9.11	-9.28
d_{excess}	n.d.	4.77	n.d.	n.d.	9.20	7.62	7.02	8.29
$d^{18}Ocorr$	n.d.	-10.32	n.d.	n.d.	-9.63	-9.96	-9.96	-9.77
ICP-MS (21.7.1999) [µg/L]							**(27.07.1999)**	**(30.07.1999)**
Li 7	n.d.	39.15513	n.d.	n.d.	41.81402	41.21333	44.31987	38.50398
B 11	n.d.	37.66069	n.d.	n.d.	39.11685	38.51713	40.60996	39.41062
Al 27	n.d.	125.04352	n.d.	n.d.	128.15028	180.45839	165.68385	201.63205
Ca 44	n.d.	309591.7899	n.d.	n.d.	329083.6199	335870.2999	329827.2899	302061.69
Sc 45	n.d.	24.37551	n.d.	n.d.	26.24909	23.58054	23.9831	23.97369
Cr 52	n.d.	2.23183	n.d.	n.d.	2.03702	1.28432	16.50041	4.1631
Fe 54	n.d.	226.56023	n.d.	n.d.	204.26335	246.29748	278.65501	275.74472
Mn 55	n.d.	0.90684	n.d.	n.d.	-0.25705	3.42803	0.74396	16.70149
Co 59	n.d.	4.18724	n.d.	n.d.	3.23523	3.98266	4.29721	3.95248
Ni 60	n.d.	29.78134	n.d.	n.d.	27.54347	28.16636	31.89331	27.68459
Cu 63	n.d.	17.84278	n.d.	n.d.	21.97254	20.30268	17.90242	24.87461
Zn 66	n.d.	11.08719	n.d.	n.d.	10.0146	18.42558	12.49507	11.54324
As 75	n.d.	9.67688	n.d.	n.d.	8.76854	9.85388	8.52377	10.6119
Se 82	n.d.	21.03781	n.d.	n.d.	25.67343	19.27382	19.67997	23.16699
Sr 88	n.d.	4078.40884	n.d.	n.d.	4048.11714	4201.01944	4449.75764	3924.731
Y 89	n.d.	0.12885	n.d.	n.d.	0.25649	0.32305	0.30022	0.29352
Cd 114	n.d.	0.15682	n.d.	n.d.	0.15868	0.18635	0.19068	0.41198
Sb 121	n.d.	0.57156	n.d.	n.d.	0.69761	0.32024	0.68402	0.4741
Ba 138	n.d.	19.85855	n.d.	n.d.	21.7847	23.51366	25.66243	28.90125
La 139	n.d.	-0.00576	n.d.	n.d.	0.05583	0.22234	0.06884	0.14554
Ce 140	n.d.	0.07465	n.d.	n.d.	0.34284	0.68981	0.18984	0.30046
Pr 141	n.d.	0.00688	n.d.	n.d.	-0.00513	0.04167	0.0489	0.0312
Nd 146	n.d.	0.11212	n.d.	n.d.	0.08244	0.25756	0.26208	0.23377
Sm 147	n.d.	0.73409	n.d.	n.d.	0.83615	0.83087	0.80005	0.86809
Eu 151	n.d.	0.0054	n.d.	n.d.	0.05781	0.00498	0.03095	0.08305
Gd 157	n.d.	0.23945	n.d.	n.d.	0.0404	0.06554	0.152	0.06805
Tb 159	n.d.	0.00436	n.d.	n.d.	0.02479	0.01577	0.04416	0.01639
Dy 162	n.d.	0.0504	n.d.	n.d.	0.05077	0.01586	0.03302	0.11839

name	Media Luna (Crater A)	Media Luna (Crater B/C)	Media Luna (Crater D)	Media Luna (Crater E)	Media Luna (Crater F)	Media Luna (Cave)	Anteojitos	Ojo de Agua de Solano
Ho 165	n.d.	0.01616	n.d.	n.d.	0.01638	0.00437	0.01213	-0.00276
Er 166	n.d.	0.05025	n.d.	n.d.	0.06158	0.06972	0.06032	0.05011
Tm 169	n.d.	0.01485	n.d.	n.d.	-0.00124	0.02616	0.01865	-0.00128
Yb 174	n.d.	0.02641	n.d.	n.d.	0.01577	0.00414	0.03676	0.01546
Lu 175	n.d.	0.0224	n.d.	n.d.	0.0016	0.00139	0.00149	0.01194
Tl 203	n.d.	0.29902	n.d.	n.d.	0.2723	0.23513	0.23896	0.19769
Pb 208	n.d.	4.83681	n.d.	n.d.	6.37818	6.978	125.83584	24.80493
Th 232	n.d.	0.0408	n.d.	n.d.	0.01933	0.005205	0.005655	0.045
U 238	n.d.	2.74024	n.d.	n.d.	3.28831	2.981775	3.36536	3.037035

(d) El Refugio area - October 1999

name	**P3**	**P9**	**P12**	**P16**	**P17**	**PSD**	**PSM**	**Chilera**	**El Peloteado**	**El Encinito I**	**El Encinito II**	**Doña Matilde**	**Huerta los Pinos**	**Las Guayabas**
longitude latitude	100°03.656' 21°55.893'	100°04.859' 21°56.451'	100°04.249' 21°55.943'	100°05.577' 21°55.691'	100°05.458' 21°55.442'	100°05.068' 21°55.150'	100°06.156' 21°56.545'	100°03.594' 21°56.941'	100°03.664' 21°57.074'	100°04.798' 21°57.181'	100°05.086' 21°57.335'	100°02.594' 21°56.508'	100°03.633' 21°56.637'	100°04.358' 21°56.264'
sampling date	14.10.99	06.10.99	06.10.99	06.10.99	06.10.99	07.10.99	07.10.99	07.10.99	13.10.99	14.10.99	14.10.99	13.10.99	12.10.99	12.10.99
sampling time	10:30	13:00	15:00	11:30	09:30	13:00	11:15	09:30	15:30	13:00	12:00	14:00	15:00	16:00
f i e l d														
Temp (°C)	24.5	24.5	28.9	25.5	24.1	25.4	25.2	24.3	24.6	29.6	25.8	23.6	24.6	28.7
pH	7.17	6.93	6.83	7.22	7.21	7.15	6.97	7.15	6.9	6.76	7	6.85	7.03	6.91
conductivity (µS/cm)	539	457	1528	598	593	433	336	1184	1450	1414	750	1841	869	1549
EH (mV)	196	222	161	174	200	124	122	165	119	140	182	134	166	35
$EH_{corrected}$ (mV)	403	429	364	380	407	330	328	372	326	343	388	341	373	239
O_2 (mg/L)	4.26	6.01	4.14	1.11	6.41	4.24	2.29	2.69	3.3	1.55	1.68	4.15	2.75	3.48
Fe (II) (mg/L)	0.04	0.02	0.17	0.06	0.01	0.02	0	0.05	0.25	0.19	0.05	0.75	0.1	1.79
Fe (ges) (mg/L)	0.01	0.01	0.01	0.05	0.06	0.01	0.04	0.05	0	0.06	0.09	0.06	0.05	1.04
Fe (III) (mg/L)	-0.03	-0.01	-0.16	-0.01	0.05	-0.01	0.04	0	-0.25	-0.13	0.04	-0.69	-0.05	-0.75
N-NO_2 (mg/L)	0.016	0.02	0.018	0.017	0.013	0.021	0.024	0.011	0.022	0.026	0.031	0.039	0.024	0.018
NO_2 (mg/L)	0.05	0.07	0.06	0.06	0.04	0.07	0.08	0.04	0.07	0.09	0.10	0.13	0.08	0.06
PO_4 (mg/L)	0.22	0.42	0.09	0.12	0.5	0.22	0.4	0.18	0.33	0.2	0.22	0.16	0.18	0.18
$PO_{4corr.}$ (mg/L)	0.21	0.41	0.08	0.11	0.49	0.21	0.39	0.17	0.32	0.19	0.21	0.15	0.17	0.17
p-value (digits)	46	100	198	120	62	65	98	70	109	240	102	140	49	119
CO_2 (mmol/L)	0.115	0.25	0.495	0.3	0.155	0.1625	0.245	0.175	0.2725	0.6	0.255	0.35	0.1225	0.2975
CO_2 (mg/L)	5.06	11	21.78	13.2	6.82	7.15	10.78	7.7	11.99	26.4	11.22	15.4	5.39	13.09
m-value (digits)	1596	1512	1995	1725	1760	1709	1403	1552	1802	2029	1872	1956	1704	1905
HCO_3(mmol/L)	3.99	3.78	4.9875	4.3125	4.4	4.2725	3.5075	3.88	4.505	5.0725	4.68	4.89	4.26	4.7625
HCO_3 (mg/L)	243.39	230.58	304.24	263.06	268.40	260.62	213.96	236.68	274.81	309.42	285.48	298.29	259.86	290.51
l a b o r a t o r y														
K (mg/L)	2.09	5.36	3.05	2.3	2.78	3.15	4.12	4.19	4.11	3.53	3.39	3.42	3.53	3.14
Na (mg/L)	14.9	24.9	19	8.38	10.13	26	24.61	47.17	39.25	22.75	15.56	37.63	42.5	19.13
Mg (mg/L)	7.23	5.31	56.69	25.57	19.3	4.34	9.72	31.96	23.09	49.82	25.52	41.01	14.77	59.54
Ca (mg/L)	91.99	66.03	296.37	88.32	89.51	65.24	44.08	209.85	282.56	274.55	124.35	393.84	145.2	300.6
Li (mg/L)	0.48	0.41	1.94	0.45	0.49	0.39	0.23	1.41	1.53	1.5	0.47	2.12	0.87	1.92
Cl (mg/L)	15	14	13	6.2	4.8	13	9.6	30	40	14	9.4	31	20	11
SO_4 (mg/L)	43.4	15.3	745	120.05	93	17.28	7.22	393	571.1	594	217.2	757	177.2	568
SiO_2 (mg/L)	32.62	54.9	20.4	19.94	25.2	54.3	48.12	41.35	57.27	26.16	30.81	36.96	122.5	21.87
F (mg/L)	0.2	0.43	1.27	1.1	0.67	0.22	0.33	0.93	0.78	1.12	0.82	0.42	0.38	1.3
NO_3 (mg/L)	56.35	36.94	1.77	2.48	3.06	15.95	11.87	30.39	71.8	14.31	20.91	51.29	75.75	1.42
B (mg/L)	0.53	n.d.	n.d.	0.45	n.d.	n.d.	n.d.	n.d.	0.52	n.d.	n.d.	n.d.	n.d.	n.d.
DOC (mgC_{org}/L)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.19	<0.1	<0.1	0.19	<0.1	<0.1

name	P3	P9	P12	P16	P17	PSD	PSM	Chilera	El Peloteado	El Encinito I	El Encinito II	Doña Matilde	Huerta los Pinos	Las Guayabas
I C P - M S [µg/L]														
Cr 52	-0.09	0.84	0.16	1.07	-0.18	2.80	1.02	0.83	0.65	0.60	0.24	0.60	0.36	0.38
Mn 55	3.29	0.59	1.17	0.89	2.13	1.05	38.69	1.91	1.81	0.99	1.50	1.89	1.61	6.83
Co 59	0.59	0.39	1.92	0.61	0.55	0.36	0.31	1.27	1.78	1.33	0.64	2.56	0.90	1.83
Ni 60	2.52	1.55	10.27	3.01	2.21	1.38	1.13	5.94	8.21	7.21	3.34	13.63	3.67	8.85
Cu 65	9.86	4.47	17.74	10.71	9.74	2.84	8.26	16.49	14.88	12.88	8.84	20.92	8.02	13.44
Zn 66	17.81	73.25	48.68	86.11	20.09	33.38	33.65	41.96	17.61	5.51	15.57	12.61	7.85	11.62
As 75	7.71	7.13	6.22	11.48	7.38	4.00	6.57	13.48	18.80	7.09	9.09	16.85	16.48	4.58
Se 82	1.88	1.12	2.49	2.05	1.55	1.00	1.21	6.28	13.07	3.84	3.31	9.03	9.24	3.59
Cd 114	0.057	0.137	0.239	0.316	0.405	0.077	0.289	0.216	0.148	0.036	0.130	0.112	0.197	0.049
Sb 121	0.17	0.11	0.50	0.13	0.18	0.16	0.17	0.32	0.51	0.50	0.34	0.49	0.64	0.49
Tl 205	0.03	0.01	0.20	0.18	0.05	0.02	0.04	0.15	0.14	0.18	0.13	0.88	0.14	0.16
Pb 208	1.29	1.01	1.22	7.75	1.87	0.39	1.19	0.65	0.17	0.04	0.47	0.15	0.04	0.01
Th 232	0.03	0.00	0.01	0.00	0.01	0.00	0.05	0.00	0.01	0.00	0.00	0.00	0.00	0.01
U 238	3.30	2.77	2.18	2.13	2.41	3.70	1.93	4.82	10.03	2.64	2.72	24.42	18.65	2.16

(e) Pastora area - October 1999

name	Chamizal	Pastora	Santo Domingo	Vergel I	Vergel II	Rancho #13
longitude	100°05.463'	100°03.529'	100°05.078'	100°04.461'	100°04.586'	100°05.080'
latitude	22°07.830'	22°08.087'	22°07.453'	22°07.606'	22°07.763'	22°06.065'
sampling date	11.10.99	12.10.99	12.10.99	13.10.99	11.10.99	11.10.99
sampling time	11:00	10:30	12:30	09:30	15:00	13:30
f i e l d						
Temp (°C)	24.6	24.4	24.1	21.7	24.5	26.2
pH	7.25	7.06	7.25	8.45	6.98	7.03
conductivity (µS/cm)	2340	3040	2950	3730	3000	3700
EH (mV)	45	105	19	105	138	128
$EH_{corrected}$ (mV)	252	312	226	314	345	333
O_2 (mg/L)	4.84	4.76	4.8	8.99	3.99	6.11
Fe (II) (mg/L)	0.33	0.29	1.06	0.22	0.31	0.61
Fe (ges) (mg/L)	0.03	0.04	0.38	0.05	0.04	0.05
Fe (III) (mg/L)	-0.3	-0.25	-0.68	-0.17	-0.27	-0.56
$N\text{-}NO_2$ (mg/L)	0.021	0.016	0.012	0.031	0.023	0.019
NO_2 (mg/L)	0.07	0.05	0.04	0.10	0.08	0.06
PO_4 (mg/L)	0.13	0.13	0.09	0.14	0.2	0.24
$PO_{4corrected}$ (mg/L)	0.12	0.12	0.08	0.13	0.19	0.23
p-value (digits)	127	69	86	0	149	149
CO_2 (mmol/L)	0.3175	0.1725	0.215	0	0.3725	0.3725
CO_2 (mg/L)	13.97	7.59	9.46	0	16.39	16.39
m-value (digits)	1201	1303	1136	628	1302	1291
HCO_3 (mmol/L)	3.0025	3.2575	2.84	1.57	3.255	3.2275
HCO_3 (mg/L)	183.15	198.71	173.24	95.77	198.56	196.88
l a b o r a t o r y						
K (mg/L)	11.36	9.9	13	17.59	11.41	11.7
Na (mg/L)	59.87	65.3	93	240.68	106.15	145.45
Mg (mg/L)	114.59	190.58	147.15	173.69	176.21	142.32
Ca (mg/L)	419.7	533.07	521.14	568.87	539	652.36
Li (mg/L)	3.24	4.11	4.08	4.88	4.42	5.32
Cl (mg/L)	38	65	200	190	70	450
SO_4 (mg/L)	1366	2021	1728	2459	1735	1881
SiO_2 (mg/L)	34.56	37.08	37.18	34.82	37.04	44.75
F (mg/L)	2.02	1.92	1.86	1.84	1.8	2.06
NO_3 (mg/L)	8.24	10.89	40.93	41.82	17.67	36.15
B (mg/L)	n.d.	0.84	0.55	1.6	0.66	1.52
DOC (mgC_{org}/L)	<0.1	0.22	0.65	6.69	0.88	1.35

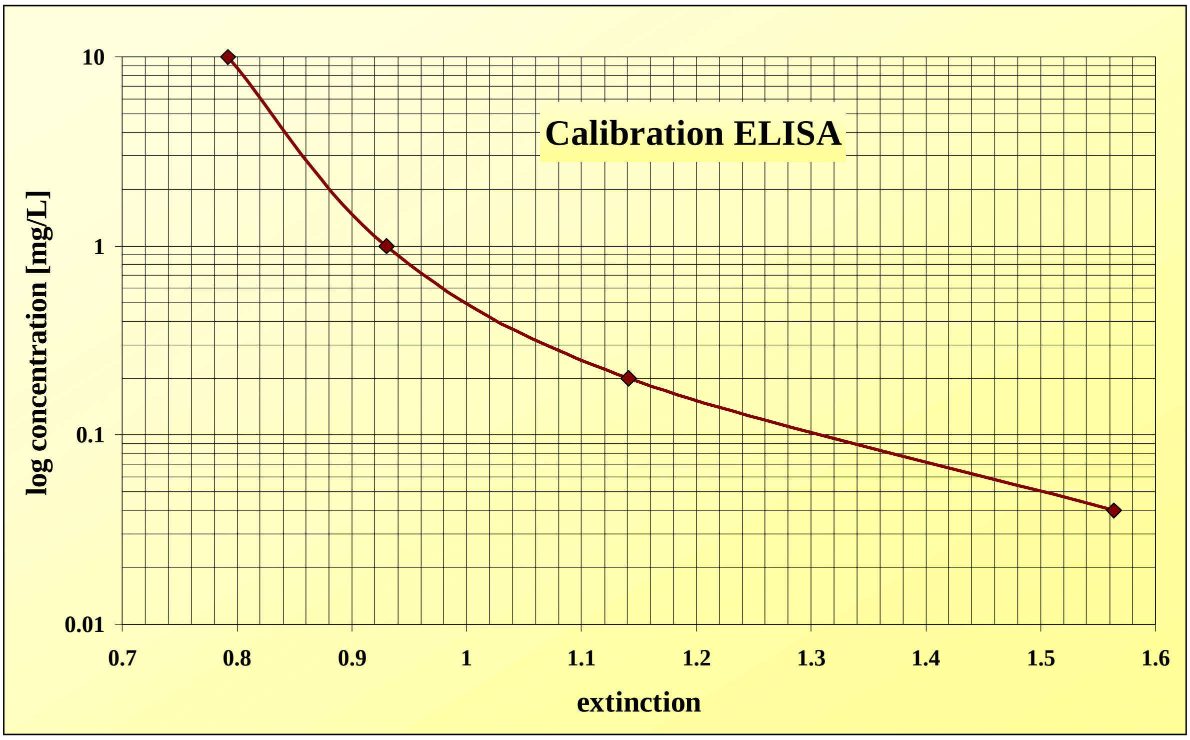
name	Chamizal	Pastora	Santo Domingo	Vergel I	Vergel II	Rancho #13
ICP-MS [µg/L]						
Cr 52	0.82	1.07	1.61	0.87	0.80	2.47
Mn 55	1.09	1.75	9.33	0.80	1.70	1.81
Co 59	2.91	3.38	3.59	3.42	2.37	4.11
Ni 60	13.60	15.45	18.63	22.32	12.57	20.70
Cu 65	28.46	32.52	34.18	33.68	22.85	32.42
Zn 66	10.05	16.99	21.09	11.59	19.17	14.55
As 75	21.76	6.70	9.61	7.24	5.82	33.43
Se 82	5.43	4.72	7.55	11.10	5.90	13.35
Cd 114	0.099	0.134	0.245	0.063	0.165	0.141
Sb 121	0.30	0.14	0.25	0.11	0.15	0.44
Tl 205	0.71	0.04	0.53	0.23	0.23	0.58
Pb 208	-0.01	0.07	0.11	0.10	0.34	0.04
Th 232	0.01	0.01	0.01	0.01	0.01	0.00
U 238	12.58	2.51	9.94	6.65	5.66	15.23

(f) Springs - October 1999

name	Media Luna	Anteojitos	Ojo de Agua de Solano	Charco Azul
longitude	100°01.391´	100°00.344´	100°05.033´	099°55.603´
latitude	21°51.581´	21°52.713´	21°59.014´	21°52.586´
depth (m)	36	14	1	1.5
sampling date	07.10.99	08.10.99	17.10.99	09.10.99
sampling time	16:30	15:00	12:00	13:00
field				
Temp (°C)	29.1	29.6	28.8	24.7
pH	6.9	7.21	6.77	7.17
conductivity (µS/cm)	1750	1833	1478	1777
EH (mV)	70	201	150	202
$EH_{corrected}$ (mV)	273	404	354	409
O_2 (mg/L)	3.06	5.11	2.8	12.34
Fe (II) (mg/L)	0.12	0.51	0.17	0.14
Fe (ges) (mg/L)	0	0.01	0.07	0.01
Fe (III) (mg/L)	-0.12	-0.5	-0.1	-0.13
$N\text{-}NO_2$ (mg/L)	0.006	0.039	0.022	0.014
NO_2 (mg/L)	0.0198	0.1287	0.0726	0.0462
PO_4 (mg/L)	0.06	0.5	0.12	0.13
$PO_{4corrected}$ (mg/L)	0.05	0.49	0.11	0.12
p-value (digits)	188	96	121	133
CO_2 (mmol/L)	0.47	0.24	0.3025	0.3325
CO_2 (mg/L)	20.68	10.56	13.31	14.63
m-value (digits)	2031	1924	1977	1456
HCO_3 (mmol/L)	5.0775	4.81	4.9425	3.64
HCO_3 (mg/L)	309.73	293.41	301.49	222.04
laboratory				
K (mg/L)	3.33	3.43	3.21	3.53
Na (mg/L)	20.8	22.15	19	22.34
Mg (mg/L)	74.13	71.16	50.66	69.96
Ca (mg/L)	354.71	367.98	288.41	350.08
Li (mg/L)	1.91	2.12	1.92	1.9
Cl (mg/L)	11	15	12	14
SO_4 (mg/L)	802	877	682.5	912
SiO_2 (mg/L)	22.33	21.52	23.34	22.75
F (mg/L)	1.4	1.46	1.3	1.43
NO_3 (mg/L)	1.19	0.75	2.7	1.64
B (mg/L)	n.d.	0.72	n.d.	n.d.
DOC (mgC_{org}/L)	<0.1	<0.1	<0.1	0.1

name	Media Luna	Anteojitos	Ojo de Agua de Solano	Charco Azul
ICP-MS [µg/L]				
Cr 52	2.12	0.37	0.29	0.32
Mn 55	0.96	1.18	5.01	1.03
Co 59	2.38	1.70	1.85	2.26
Ni 60	12.93	8.16	8.92	11.69
Cu 65	19.03	13.23	15.55	20.67
Zn 66	25.49	10.76	8.71	13.81
As 75	5.78	6.08	6.47	6.42
Se 82	2.79	2.66	3.11	3.46
Cd 114	0.057	0.236	0.082	0.118
Sb 121	0.53	0.46	0.54	0.53
Tl 205	0.19	0.21	0.17	0.23
Pb 208	0.15	0.55	0.07	0.32
Th 232	0.00	0.00	0.00	0.05
U 238	2.06	2.55	1.80	4.03

App.No.25.: Calibration and results for ELISA tests on selected wells in El Refugio
(lower limits of detection 4,4-DDT 40 µg/L, 4,4-DDD 10 µg/L, 2,4-DDT 4000 µg/L, 2,4-DDD 400 µg/L)



	extinction at 450 nm	concentration mg/L
calibration	1.564	0
	1.141	0.2
	0.93	1
	0.792	10

name	extinction at 450nm	concentration (mg/L)	concentration (µg/L)	remarks
P3	1.552	0.043	43	concentrations below or too close to lower limit of detection in all samples!
P9	1.498	0.05	50	
P12	1.473	0.055	55	
P16	1.443	0.06	60	
P17	1.671	<0	0	
PSD	1.58	<0	0	
Chilera	1.584	<0	0	
El Peloteado	1.62	<0	0	
El Encinito I	1.684	<0	0	
Cave Media Luna	1.655	<0	0	

App.No.26.: Results for the determination of chlorinated and phosphorous pesticides

a) Quantitative results from the GC-ECD detection at the university in Freiberg (chlorinated pesticides) [drinking water standards from EPA (2000, http://www.pura.com/contamin.htm) and WHO (1996), German drinking water standards are generally 100 ng/L for single pesticide substances and 500 ng/L for the sum of all pesticides (TrinkwV 1990)]

chlorinated pesticide	standard solution	**P3**	**P9**	**P12**	**P16**	**P17**	**PSD**	**Chilera**	**Peloteado**	**Encinito I**	drinking water standards
area of detected peak											
α-HCH	402.8848	3129	981	4616	2040	637		1694	1663	1890	
β-HCH	195.1176	6262	2204	212	823			616	500	468	
γ-HCH	383.239		6448	291	7874	1796		8161	7618	7810	
Heptachlor	260.4188	5733	5163	4979	6030	1109		6438	6386	6308	
cis-Hepta-chlorepoxid	1196.5169			3625		3776		3972	4546	4895	
Aldrin	723.1687	7805	7277	8691	8565	3666	309	8568	8899	9187	
Dieldrin	3218.2821	16008	14297	12894	13320	3026	377	13532	17614	14224	
Endrin	458.2483	15032		6309	8600	5365		17530	10462	15382	
2,4´-DDD	774.1818	11471	10417	10885	11602	11390	1950	11968	10298	11403	
4,4´-DDD	2514.9217	7382	21675	10989	13028	15652		4675	13298		
2,4´-DDT	1580.7596	10995	7175	6768	7825	7500		8278	8599	6838	
4,4´-DDT	1912.345	15151	14663	13220	15907	15671		16052	16618	15648	
concentration in laboratory sample (calculated from standard solution) [µg/L]											
α-HCH	0.6	5	1	7	3	1	---	3	2	3	
β-HCH	2.57	82	29	3	11	---	---	8	7	6	
γ-HCH	2.83	---	48	2	58	13	---	60	56	58	
Heptachlor	0.6	13	12	11	14	3	---	15	15	15	
cis-Hepta-chlorepoxid	1.92	---	---	6	---	6	---	6	7	8	
Aldrin	1.24	13	12	15	15	6	1	15	15	16	
Dieldrin	4.82	24	21	19	20	5	1	20	26	21	
Endrin	0.61	20	---	8	11	7	---	23	14	20	
2,4´-DDD	4.75	70	64	67	71	70	12	73	63	70	
4,4´-DDD	4.52	13	39	20	23	28	---	8	24	---	
2,4´-DDT	5.53	38	25	24	27	26	---	29	30	24	
4,4´-DDT	6.27	50	48	43	52	51	---	53	54	51	
concentration in well sample (considering enrichment in the field) [ng/L]											
enrichment volume [ml]		*276*	*226*	*231*	*359*	*346*	*278*	*289*	*256*	*270*	
enrichment factor		*76*	*51*	*53*	*129*	*120*	*77*	*84*	*66*	*73*	
α-HCH		61	29	129	24	8	---	30	38	39	200 EPA
β-HCH		1083	568	52	84	---	---	97	100	85	
γ-HCH		---	932	40	451	111	---	722	858	791	2000 WHO
Heptachlor		173	233	215	108	21	---	178	225	199	400 EPA 30 WHO
cis-Heptachlorepoxid		---	---	109	---	51	---	76	111	108	200 EPA 30 WHO
Aldrin		176	244	279	114	53	7	176	233	216	30 WHO
Dieldrin		315	419	362	155	38	7	243	403	292	30 WHO
Endrin		263	---	157	89	60	---	279	213	281	2000 EPA
2,4´-DDD		924	1251	1252	552	584	155	879	964	960	2000 WHO
4,4´-DDD		174	763	370	182	235	---	101	365	---	
2,4´-DDT		505	491	444	212	219	---	347	459	328	
4,4´-DDT		652	941	812	405	429	---	630	831	704	
sum of determined organochlorinated pesticides		4326	5872	4222	2375	1808	169	3757	4002	4800	500 (TrinkwV 1990)

b) Quantitative results from the GC-MS detection at the Biologische Bundesanstalt für Land- und Forstwirtschaft Berlin-Dahlem (Prof. Dr. W. Pestemer) (chlorinated pesticides)

chlorinated pesticide	standard 10 µg/L	P3	P9	Chilera	El Peloteado	Encinito I	drinking water standards
area of detected peak							
α-HCH	7332	12255	5549	6907	6379	9915	
β-HCH	8441	11618	5167	5632	5119	4276	
γ-HCH	14879	68812	56478	45110	66140	68785	
Aldrin	2144	17177	9374	10694	9925	11616	
2,4´-DDD	17034	111854	58006	61935	56838	80358	
4,4´-DDD	32040	131095	56703	69265	54808	99362	
2,4´-DDT	32040	133074	74723	76729	68964	77672	
4,4´-DDT	12212	170794	80698	89653	73799	113526	
2,4´-DDE	14924	---	---	---	---	---	
4,4´-DDE	9733	142092	71216	75734	63187	86415	
concentration in laboratory sample (calculated from standard solution) [µg/L]							
α-HCH	10.00	16.71	7.57	9.42	8.70	13.52	
β-HCH	10.00	13.76	6.12	6.67	6.06	5.07	
γ-HCH	10.00	46.25	37.96	30.32	44.45	46.23	
Aldrin	10.00	80.12	43.72	49.88	46.29	54.18	
2,4´-DDD	10.00	65.67	34.05	36.36	33.37	47.18	
4,4´-DDD	10.00	40.92	17.70	21.62	17.11	31.01	
2,4´-DDT	10.00	41.53	23.32	23.95	21.52	24.24	
4,4´-DDT	10.00	139.86	66.08	73.41	60.43	92.96	
2,4´-DDE	10.00	---	---	---	---	---	
4,4´-DDE	10.00	145.99	73.17	77.81	64.92	88.79	
concentration in well sample (considering enrichment in the field) [ng/L]							
enrichment volume [ml]		*276*	*226*	*289*	*256*	*270*	
enrichment factor		*76*	*51*	*84*	*66*	*73*	
α-HCH		219	148	113	133	185	200 EPA
β-HCH		181	120	80	93	69	
γ-HCH		607	743	363	678	634	2000 WHO
Aldrin		1052	856	597	706	743	30 WHO
2,4´-DDD		862	667	435	509	647	
4,4´-DDD		537	346	259	261	425	
2,4´-DDT		545	457	287	328	333	2000 WHO
4,4´-DDT		1836	1294	879	922	1275	
2,4´-DDE		---	---	---	---	---	
4,4´-DDE		1916	1433	932	991	1218	

c) Qualitative results from the GC-ECD at the university Freiberg

chlorinated pesticide	P3	P9	P12	P16	P17	PSD	Chilera	Peloteado	Encinito I
peaks detected									
α-Endosulfan	yes	yes	yes	yes	yes	yes	yes	yes	yes
trans Heptachlorepoxide	yes	yes	no	yes	yes	no	no	no	no
2,4-DDE	no	no	no	no	no	no	yes	no	no
phosphorous pesticide	P3	P9	P12	P16	P17	PSD	Chilera	Peloteado	Encinito I
peaks detected									
Parathion-Methyl	yes	yes	yes	yes	yes	yes	no	yes	yes
Fenchlorphos	no	no	no	no	no	no	yes	no	no
Chlorpyriphos	no	no	no	no	yes	no	no	no	no

App.No.27.: Cluster statistics - samples June/July 1999

(cluster model *4 cluster*, mininum (min), maximum (max), mean values (mean) and standard deviation (dev) within the 4 groups)

name	El Refugio (1)				El Refugio (2)				Springs (3)				Pastora (4)			
	min	**max**	**mean**	**dev**	**min**	**max**	**mean**	**dev**	**min**	**max**	**mean**	**dev**	**min**	**max**	**mean**	**dev**
Temp [°C]	24.6	28.5	26.01	1.25	24.1	28.9	27.15	2.09	28	33	29.58	1.51	24.2	26.9	25.2	0.9
pH	7.04	7.17	7.10	0.06	6.73	6.93	6.82	0.09	7	7	7.06	0.10	6.86	7.19	7.03	0.10
conduc. (µS/cm)	386	911	597.86	192.67	1242	1796	1525	205	1646	1825	1775	56	2330	3670	3130	426
EH (mV)	295	462	366	67	229	407	323	58					162	474	350	87
O_2 (mg/L)	0	5.9	3.40	3.05	0.8	4.9	3.03	2.07					2.75	7.30	5.55	1.36
NO_2 (mg/L)	0.050	0.158	0.113	0.042	0.046	0.333	0.140	0.101					0.046	0.168	0.087	0.043
PO_4 (mg/L)	0.2	0.5	0.29	0.10	0.15	0.6	0.28	0.18					0.11	0.98	0.29	0.27
CO_2 (mg/L)	4.29	23.32	9.37	6.40	10.78	28.38	19.05	6.73	16	39	27.53	6.61	11.11	17.49	14.19	2.56
HCO_3 (mg/L)	216.55	279.99	239.93	21.30	245.07	292.50	270.03	21.87	297.99	307.59	301.76	3.35	174.92	222.04	197.45	15.89
K (mg/L)	2.08	6.24	3.81	1.41	3.21	4.76	3.80	0.60	3	4	3.45	0.10	11.10	16.01	12.65	1.77
Na (mg/L)	11.48	36.89	21.65	8.90	18.72	37.88	27.63	8.10	18	20	19.03	0.54	51.57	251.43	105.82	59.56
Mg(mg/L)	7.84	24.72	16.11	7.44	28.34	62.11	49.85	14.26	58	69	65.22	3.12	106.53	275.50	172.65	63.25
Ca (mg/L)	59.67	142.21	90.21	33.46	218.79	308.3	280.12	37.55	320	371	349.84	14.63	430.10	666.32	552.13	64.93
Li (mg/L)	0.01	0.04	0.02	0.01	0.04	0.06	0.05	0.01								
Cl (mg/L)	4	11.5	8.39	2.78	5	24	13.83	7.91	7	12	9.44	1.37	12	80	34.61	22.45
SO_4(mg/L)	7.78	279.90	97.33	104.00	487.28	911.3	705.44	167.85	804	1023	940.70	64.95	1406.30	2462.70	1875.31	303.08
SiO_2(mg/L)	27.37	53.93	42.10	11.79	21.59	49.97	32.47	11.54	20	22	20.88	0.59	24.35	41.55	34.73	5.07
F (mg/L)	0.24	0.86	0.49	0.24	0.442	1.3	1.02	0.33	1	1	1.40	0.00	1.31	2.27	1.85	0.27
NO_3(mg/L)	4.52	43.41	22.45	13.67	1.45	41.72	20.07	17.80	1	2	1.45	0.33	0.95	24.67	14.82	7.21
As (ug/L)	3.59	8.69	6.62	2.14	3.33	10.33	7.11	2.85	8.20	9.05	8.52	0.28	4.15	42.76	15.24	13.05
B (mg/L)													0.20	2.53	1.41	0.82
T.U.	-0.11	2.57	1.03	0.97	-0.16	1.97	0.69	1.13	0.70	1.60	1.14	0.40	0.16	0.81	0.55	0.21
d^2H	-58.30	-51.93	-55.99	2.40	-62.95	-56.92	-59.76	2.47	-66.62	-65.86	-66.06	0.32	-55.99	-53.03	-54.84	1.19
$d^{18}O$	-8.48	-7.38	-7.96	0.50	-9.02	-7.56	-8.26	0.60	-9.40	-8.83	-9.18	0.22	-7.66	-7.05	-7.43	0.24
ICP [µg/L]																
Li 7	11.22	14.62	13.14	1.31	22.50	30.92	26.61	4.50	38.50	44.32	41.00	2.31	83.34	140.40	102.03	20.65
B 11	14.69	39.39	24.61	10.19	22.94	31.09	27.87	3.63	37.66	40.61	39.06	1.09	165.96	352.07	282.26	66.74
Al 27	79.63	266.49	189.09	71.68	154.07	856.01	606.51	309.61	125.04	201.63	160.19	33.24	138.83	1127.27	511.45	401.36
Mn 55	0.16	4.83	2.48	1.68	1.76	1378.29	348.87	686.28	-0.26	16.70	4.30	7.06	1.63	56.06	18.93	20.63
Fe 54	129.65	680.48	329.16	242.18	219.98	668.48	349.53	213.29	204.26	278.66	246.30	31.90	161.85	1154.75	460.37	350.53
Cr 52	0.89	1.58	1.10	0.29	1.34	1.77	1.52	0.20	1.28	16.50	5.24	6.38	1.36	3.86	2.36	0.76
Co 59	0.43	1.22	0.89	0.29	2.72	10.80	5.07	3.87	3.24	4.30	3.93	0.41	2.68	8.78	4.54	2.00
Ni 60	10.50	13.21	11.99	1.08	18.78	26.36	23.45	3.28	27.54	31.89	29.01	1.84	35.04	58.92	41.90	7.98
Cu 63	9.60	17.49	13.39	2.94	24.40	77.51	38.44	26.07	17.84	24.87	20.58	2.96	12.01	37.28	18.56	8.48
Zn 66	29.23	115.73	68.24	34.32	21.27	167.66	64.76	69.23	10.01	18.43	12.71	3.32	10.32	81.93	42.29	28.49
Cd 114	0.13	0.38	0.20	0.10	0.30	0.47	0.37	0.07	0.16	0.41	0.22	0.11	0.06	0.50	0.27	0.15
As 75	5.30	10.89	7.35	2.22	9.89	23.53	16.12	5.62	8.52	10.61	9.49	0.85	12.48	45.40	20.80	11.06
Se 82	5.97	14.28	9.92	3.19	22.78	29.46	25.96	2.74	19.27	25.67	21.77	2.66	32.21	68.28	48.27	11.63
Sr 88	310.43	565.32	437.67	104.27	1840.73	3071.69	2713.82	584.02	3924.73	4449.76	4140.41	198.90	8568.73	11819.28	9931.62	1343.19
Sb 121	0.09	0.39	0.25	0.12	0.12	0.61	0.38	0.23	0.32	0.70	0.55	0.16	0.18	0.81	0.43	0.20
Ba 138	79.02	169.25	134.91	35.12	32.13	64.66	49.12	15.25	19.86	28.90	23.94	3.50	12.85	34.91	22.74	6.94
Sc 45	15.53	36.49	24.83	10.29	32.26	52.01	42.06	8.49	23.58	26.25	24.43	1.05	33.73	42.85	36.80	3.52
Y 89	0.05	1.39	0.35	0.58	0.22	0.51	0.37	0.12	0.13	0.32	0.26	0.08	0.24	9.62	1.61	3.53
La 139	0.02	5.34	1.15	2.35	0.10	1.02	0.50	0.38	-0.01	0.22	0.10	0.09	0.01	6.78	1.21	2.47
Ce 140	0.06	3.24	1.49	1.53	0.20	19.07	11.58	8.04	0.07	0.69	0.32	0.23	0.20	26.52	7.36	10.17
Pr 141	0.00	1.20	0.26	0.53	-0.01	0.17	0.07	0.09	-0.01	0.05	0.02	0.02	0.00	2.11	0.36	0.77
Nd 146	0.13	3.83	0.89	1.65	0.08	0.53	0.33	0.19	0.08	0.26	0.19	0.09	0.03	7.56	1.21	2.81
Sm 147	0.74	1.54	0.98	0.32	0.70	0.99	0.85	0.13	0.73	0.87	0.81	0.05	0.74	2.95	1.14	0.80
Eu 151	0.02	0.15	0.07	0.05	0.02	0.06	0.04	0.02	0.00	0.08	0.04	0.03	0.02	0.60	0.12	0.21
Gd 157	0.02	0.79	0.26	0.31	0.09	0.57	0.22	0.23	0.04	0.24	0.11	0.08	0.08	2.07	0.47	0.72
Tb 159	0.01	0.07	0.03	0.03	0.00	0.03	0.02	0.01	0.00	0.04	0.02	0.01	0.00	0.37	0.07	0.13
Dy 162	0.01	0.42	0.11	0.17	0.03	0.14	0.07	0.05	0.02	0.12	0.05	0.04	0.04	2.37	0.39	0.87
Ho 165	0.00	0.05	0.02	0.02	0.00	0.02	0.01	0.01	0.00	0.02	0.01	0.01	0.01	0.43	0.08	0.16
Er 166	0.01	0.13	0.04	0.05	0.02	0.07	0.04	0.02	0.05	0.07	0.06	0.01	0.00	1.05	0.18	0.39
Tm 169	0.00	0.04	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.03	0.01	0.01	0.00	0.15	0.03	0.05
Yb 174	0.00	0.08	0.03	0.04	0.00	0.08	0.03	0.03	0.00	0.04	0.02	0.01	0.02	0.71	0.14	0.25
Lu 175	0.00	0.04	0.01	0.02	-0.01	0.02	0.01	0.01	0.00	0.02	0.01	0.01	0.00	0.13	0.02	0.05
Tl 203	0.00	0.17	0.08	0.07	0.04	0.22	0.12	0.08	0.20	0.30	0.25	0.04	0.08	0.96	0.42	0.37
Pb 208	5.42	12.15	7.76	2.60	6.51	9.13	7.99	1.15	4.84	125.84	33.77	52.11	3.58	16.90	6.96	4.53
Th 232	0.03	0.42	0.14	0.16	0.03	0.16	0.10	0.05	0.01	0.05	0.02	0.02	0.02	0.18	0.08	0.07
U 238	2.25	3.95	2.82	0.69	2.75	476.20	223.38	253.99	2.74	3.37	3.08	0.25	3.80	657.90	180.55	284.58

App.No.28.: Cluster statistics - samples October 1999

(cluster model *4 cluster*, mininum (min), maximum (max), mean values (mean) and standard deviation (dev) within the 4 groups)

name	El Refugio 1 Oct				El Refugio 2 Oct				Springs Oct				Pastora Oct			
	min	**max**	**mean**	**dev**	**min**	**max**	**mean**	**dev**	**min**	**max**	**mean**	**dev**	**min**	**max**	**mean**	**dev**
Temp (°C)	24.1	25.8	24.95	0.60	23.6	29.6	26.62	2.72	24.70	29.60	28.05	2.26	21.70	26.20	24.25	1.45
pH	6.93	7.22	7.09	0.12	6.76	7.15	6.90	0.13	6.77	7.21	7.01	0.21	6.98	8.45	7.34	0.56
conduc. (µS/cm)	336	869	572	173	1184	1841	1494	214	1478	1833	1710	158	2340	3730	3127	523
EH (mV)	328	429	380	36	239	372	331	48	273	409	360	63	226	345	297	47
O_2 (mg/L)	1.11	6.41	3.59	1.96	1.55	4.15	3.22	0.99	2.80	12.34	5.83	4.46	3.99	8.99	5.58	1.80
NO_2(mg/L)	0.043	0.102	0.068	0.019	0.036	0.129	0.074	0.032	0.020	0.129	0.067	0.047	0.040	0.102	0.067	0.021
PO_4 (mg/L)	0.11	0.49	0.28	0.14	0.08	0.32	0.18	0.08	0.05	0.49	0.19	0.20	0.08	0.23	0.15	0.05
CO_2(mg/L)	5.06	13.2	8.83	3.08	7.7	26.4	16.06	6.86	10.56	20.68	14.80	4.27	0.00	16.39	10.63	6.34
HCO_3 (mg/L)	213.96	285.48	253.17	22.73	236.68	309.42	285.66	26.87	222.04	309.73	281.67	40.31	95.77	198.71	174.38	39.85
K (mg/L)	2.09	5.36	3.34	1.05	3.05	4.19	3.57	0.48	3.21	3.53	3.38	0.14	9.90	17.59	12.49	2.68
Na (mg/L)	8.38	42.5	20.87	11.08	19	47.17	30.82	12.05	19.00	22.34	21.07	1.54	59.87	240.68	118.41	67.42
Mg (mg/L)	4.34	25.57	13.97	8.69	23.09	59.54	43.69	14.33	50.66	74.13	66.48	10.69	114.59	190.58	157.42	27.88
Ca (mg/L)	44.08	145.2	89.34	32.79	209.85	393.84	292.96	59.33	288.41	367.98	340.30	35.41	419.70	652.36	539.02	75.27
Li (mg/L)	0.23	0.87	0.47	0.18	1.41	2.12	1.74	0.29	1.90	2.12	1.96	0.11	3.24	5.32	4.34	0.72
Cl (mg/L)	4.8	20	11.50	4.99	11	40	23.17	12.06	11.00	15.00	13.00	1.83	38	450	168.83	153.71
SO_4 (mg/L)	7.22	217.2	86.33	79.71	393	757	604.68	134.38	682.50	912.00	818.38	101.54	1366	2459	1865	363.90
SiO_2(mg/L)	19.94	122.5	48.55	32.68	20.4	57.27	34.00	14.13	21.52	23.34	22.49	0.77	34.56	44.75	37.57	3.71
F (mg/L)	0.2	1.1	0.52	0.32	0.42	1.3	0.97	0.34	1.30	1.46	1.40	0.07	1.80	2.06	1.92	0.10
NO_3 (mg/L)	2.48	75.75	27.91	26.44	1.42	71.8	28.50	28.45	0.75	2.70	1.57	0.84	8.24	41.82	25.95	15.42
B (mg/L)	0.45	0.53	0.49	0.06					0.72	0.72	0.72		0.55	1.60	1.03	0.49
DOC (mgC_{org}/L)	<0.1	<0.1	<0.1		0.19	0.19	0.19	0.00	<0.1	0.10	0.10		<0.1	6.69	1.96	2.68

App.No.29.: Share of main ions for water type classification (samples from June/July 1999)

(percentage calculated from mmol(eq)/L concentrations (App.No.16), criteria for water type >25%)

	cations = 100%				anions = 100%				water type
[%]	K	Na	Mg	Ca	Cl	SO_4	NO_3	HCO_3	
group (1)									
P3	0.73	6.89	21.21	71.17	3.74	30.22	10.31	55.74	Ca-HCO_3-SO_4
P9	3.08	24.03	12.47	60.42	6.85	6.14	12.06	74.95	Ca-HCO_3
P16	1.22	10.55	28.03	60.20	1.98	25.53	1.28	71.22	Ca-Mg-HCO_3-SO_4
P17	1.99	17.83	15.16	65.01	3.46	3.97	4.22	88.34	Ca-HCO_3
PSD	1.68	20.67	14.37	63.28	5.49	7.30	5.52	81.69	Ca-HCO_3
El Encinito II	0.96	7.95	22.36	68.73	2.99	43.77	3.56	49.68	Ca-HCO_3-SO_4
Huerta los Pinos	1.22	14.90	17.97	65.91	2.68	55.36	4.02	37.94	Ca-SO_4-HCO_3
group (2)									
P12	0.39	3.85	24.17	71.59	0.80	77.01	0.11	22.08	Ca-SO_4
Chilera	0.78	10.55	18.75	69.92	3.23	68.19	2.99	25.59	Ca-SO_4-HCO_3
El Peloteado	0.68	8.72	14.38	76.22	4.39	65.76	3.76	26.08	Ca-SO_4-HCO_3
El Encinito I	0.44	4.87	22.23	72.45	1.35	75.10	0.82	22.73	Ca-SO_4
Doña Matilde	0.44	6.92	21.75	70.89	2.66	73.86	3.17	20.30	Ca-SO_4
Las Guayabas	0.40	4.01	23.49	72.10	0.66	76.73	0.11	22.50	Ca-SO_4
group (3)									
Media Luna (Crater A)	0.36	3.35	22.74	73.55	1.06	78.51	0.09	20.34	Ca-SO_4
Media Luna (Crater B/C)	0.37	3.34	22.22	74.07	1.02	78.81	0.10	20.07	Ca-SO_4
Media Luna (Crater D)	0.36	3.46	23.84	72.35	0.96	79.02	0.09	19.93	Ca-SO_4
Media Luna (Crater E)	0.36	3.52	22.75	73.37	1.11	79.45	0.08	19.36	Ca-SO_4
Media Luna (Crater F)	0.37	3.48	22.43	73.72	1.26	79.15	0.06	19.53	Ca-SO_4
Media Luna (Cave)	0.38	3.53	23.14	72.95	1.12	79.23	0.12	19.53	Ca-SO_4
Anteojitos	0.37	3.47	21.63	74.53	1.12	80.38	0.07	18.43	Ca-SO_4
Ojo de Agua de Solano	0.42	3.77	22.09	73.72	0.90	76.29	0.14	22.67	Ca-SO_4
group (4)									
La Cabana	0.54	7.35	40.63	51.47	0.92	92.49	0.03	6.56	Ca-Mg-SO_4
Pastora	0.63	6.43	32.83	60.11	0.70	92.18	0.50	6.62	Ca-Mg-SO_4
Chamizal	0.92	6.84	26.75	65.49	4.63	85.74	0.39	9.24	Ca-Mg-SO_4
San Isidro	0.65	10.28	21.12	67.95	2.29	89.32	0.72	7.67	Ca-SO_4
Santo Domnigo	0.92	9.57	25.36	64.15	1.22	90.94	0.52	7.31	Ca-Mg-SO_4
Vergel I	0.80	21.28	25.97	51.95	2.06	90.49	0.86	6.59	Ca-Mg-SO_4
Vergel II	0.52	6.59	40.98	51.91	0.84	92.68	0.39	6.09	Ca-Mg-SO_4
Rancho #13	0.68	11.32	24.17	63.82	4.33	88.19	0.55	6.92	Ca-Mg-SO_4
La Gloria	0.74	7.63	31.13	60.50	3.14	88.35	0.90	7.61	Ca-Mg-SO_4

App.No.30.: Share of main ions for water type classification (samples from October 1999)

(percentage calculated from mmol(eq)/L concentrations (App.No.16), criteria for water type >25%)

	cations = 100%				anions = 100%				water type
[%]	K	Na	Mg	Ca	Cl	SO_4	NO_3	HCO_3	
group (1)									
P3	0.91	11.01	10.11	77.98	6.47	13.82	18.73	60.99	$Ca-HCO_3$
P9	2.77	21.87	8.82	66.54	7.46	6.02	15.16	71.36	$Ca-HCO_3$
P16	0.85	5.26	30.34	63.55	2.48	35.51	0.77	61.24	$Ca-Mg-HCO_3-SO_4$
P17	1.08	6.71	24.19	68.02	2.07	29.62	1.02	67.29	$Ca-HCO_3-SO_4$
PSD	1.67	23.44	7.40	67.48	6.86	6.73	6.49	79.92	$Ca-HCO_3$
PSM	2.52	25.64	19.16	52.68	6.47	3.59	6.16	83.77	$Ca-Na-HCO_3$
El Encinito II	0.96	7.46	23.16	68.43	2.67	45.58	4.58	47.16	$Ca-HCO_3-SO_4$
Huerta los Pinos	0.87	17.78	11.69	69.67	5.55	36.32	16.21	41.92	$Ca-HCO_3-SO_4$
group (2)									
P12	0.38	4.06	22.91	72.64	1.75	74.21	0.18	23.85	$Ca-SO_4$
Chilera	0.70	13.44	17.23	68.62	6.24	60.31	4.87	28.59	$Ca-SO_4-HCO_3$
El Peloteado	0.59	9.58	10.67	79.16	5.91	62.31	8.18	23.60	$Ca-SO_4$
El Encinito I	0.48	5.24	21.71	72.57	2.18	68.16	1.71	27.95	$Ca-SO_4-HCO_3$
Doña Matilde	0.35	6.61	13.63	79.40	3.86	69.62	4.92	21.59	$Ca-SO_4$
Las Guayabas	0.39	4.00	23.54	72.08	1.49	75.48	0.15	22.88	$Ca-SO_4$
group (3)									
Media Luna	0.34	3.65	24.61	71.40	1.40	75.52	0.12	22.96	$Ca-SO_4$
Anteojitos	0.35	3.81	23.17	72.67	1.80	77.68	0.07	20.46	$Ca-SO_4$
Ojo de Agua de Solano	0.42	4.24	21.41	73.92	1.73	72.69	0.30	25.28	$Ca-SO_4-HCO_3$
Charco Azul	0.37	4.00	23.70	71.93	1.71	82.35	0.15	15.78	$Ca-SO_4$
group (4)									
Pastora	0.56	6.26	34.56	58.62	3.87	88.76	0.50	6.87	$Ca-Mg-SO_4$
Chamizal	0.87	7.83	28.34	62.96	3.28	86.99	0.55	9.18	$Ca-Mg-SO_4$
Santo Domingo	0.78	9.52	28.50	61.20	12.44	79.34	1.96	6.26	$Ca-Mg-SO_4$
Vergel I	0.84	19.53	26.67	52.96	9.08	86.72	1.54	2.66	$Ca-Mg-SO_4$
Vergel II	0.63	9.97	31.31	58.09	4.73	86.55	0.92	7.80	$Ca-Mg-SO_4$
Rancho #13	0.59	12.43	23.01	63.97	22.72	70.10	1.41	5.78	$Ca-Mg-SO_4$

App.No.31.: Correlation analysis (samples from June/July 1999)

(Program: Joker; method: Spearman for not normal distributed variables;
listed are the correlation coefficient in line 1, the number of cases in line 2 and the significancy in line 3 for each variable, the whole matrix is horizontally divided in 4 tables (Al-$\delta^{18}O$; δ^2H-Lu, Mg-Se, SiO_2-Zn) with all variables displayed vertically; the lower half triangle of the matrix is crossed out respectively cut since it is identical with the upper one; significancies <0.05 are marked in green, <0.01 in blue, <0.001 in red, "0" = significancy <0.0005)

	Al	As	As ICP	B	Ba	Ca	Cd	Ce	Cl	Co	CO_2	cond.	Cr	Cu	$\delta^{18}O$
Al	1	0.455 21 0.019	0.019 21 0.447	0.066 21 0.384	0.218 21 0.172	0.204 21 0.19	0.143 21 0.271	0.877 21 0	0.263 21 0.124	0.142 21 0.273	0.009 21 0.46	0.203 21 0.191	0.156 21 0.253	0.203 21 0.191	0.479 21 0.014
As	~~0.455~~ ~~21~~ ~~0.019~~	1	0.496 21 0.01	0.503 21 0.009	-0.46 21 0.017	0.642 21 0.001	0.274 21 0.114	0.325 21 0.074	0.708 21 0	0.357 21 0.054	0.148 21 0.264	0.647 21 0.001	0.417 21 0.029	0.191 21 0.206	0.528 21 0.007
As ICP	~~0.019~~ ~~21~~ ~~0.447~~	~~0.496~~ ~~21~~ ~~0.01~~	1	0.304 21 0.089	-0.592 21 0.002	0.445 30 0.007	0.01 21 0.458	-0.055 21 0.4	0.519 30 0.002	0.536 21 0.006	0.101 30 0.3	0.482 30 0.004	0.457 21 0.018	0.212 21 0.18	0.294 21 0.097
B	~~0.066~~ ~~21~~ ~~0.384~~	~~0.503~~ ~~21~~ ~~0.009~~	~~0.304~~ ~~21~~ ~~0.089~~	1	-0.703 21 0	0.839 21 0	-0.043 21 0.416	-0.116 21 0.312	0.566 21 0.004	0.408 21 0.032	0.318 21 0.079	0.853 21 0	0.603 21 0.002	-0.119 21 0.306	0.266 21 0.122
Ba	~~0.218~~ ~~21~~ ~~0.172~~	~~-0.46~~ ~~21~~ ~~0.017~~	~~-0.592~~ ~~21~~ ~~0.002~~	~~-0.703~~ ~~21~~ ~~0~~	1	-0.791 21 0	0.057 21 0.396	0.322 21 0.075	-0.477 21 0.014	-0.594 21 0.002	-0.579 21 0.003	-0.834 21 0	-0.614 21 0.002	-0.151 21 0.261	-0.068 21 0.382
Ca	~~0.204~~ ~~21~~ ~~0.19~~	~~0.642~~ ~~21~~ ~~0.001~~	~~0.445~~ ~~30~~ ~~0.007~~	~~0.839~~ ~~21~~ ~~0~~	~~-0.791~~ ~~21~~ ~~0~~	1	0.089 21 0.35	0.118 21 0.308	0.585 30 0.001	0.63 21 0.001	0.373 30 0.021	0.975 30 0	0.698 21 0	0.058 21 0.396	0.308 21 0.086
Cd	~~0.143~~ ~~21~~ ~~0.271~~	~~0.274~~ ~~21~~ ~~0.114~~	~~0.01~~ ~~21~~ ~~0.458~~	~~-0.043~~ ~~21~~ ~~0.416~~	~~0.057~~ ~~21~~ ~~0.396~~	~~0.089~~ ~~21~~ ~~0.35~~	1	0.164 21 0.243	-0.103 21 0.331	0.453 21 0.019	0.134 21 0.284	-0.014 21 0.454	0.204 21 0.19	0.474 21 0.014	-0.027 21 0.437
Ce	~~0.877~~ ~~21~~ ~~0~~	~~0.325~~ ~~21~~ ~~0.074~~	~~-0.055~~ ~~21~~ ~~0.4~~	~~-0.116~~ ~~21~~ ~~0.312~~	~~0.322~~ ~~21~~ ~~0.075~~	~~0.118~~ ~~21~~ ~~0.308~~	~~0.164~~ ~~21~~ ~~0.243~~	1	0.217 21 0.174	0.068 21 0.382	0.113 21 0.315	0.068 21 0.382	-0.09 21 0.35	0.236 21 0.152	0.335 21 0.067
Cl	~~0.263~~ ~~21~~ ~~0.124~~	~~0.708~~ ~~21~~ ~~0~~	~~0.519~~ ~~30~~ ~~0.002~~	~~0.566~~ ~~21~~ ~~0.004~~	~~-0.477~~ ~~21~~ ~~0.014~~	~~0.585~~ ~~30~~ ~~0.001~~	~~-0.103~~ ~~21~~ ~~0.331~~	~~0.217~~ ~~21~~ ~~0.174~~	1	0.228 21 0.161	-0.183 30 0.168	0.649 30 0	0.234 21 0.154	0.066 21 0.384	0.612 21 0.002
Co	~~0.142~~ ~~21~~ ~~0.273~~	~~0.357~~ ~~21~~ ~~0.054~~	~~0.536~~ ~~21~~ ~~0.006~~	~~0.408~~ ~~21~~ ~~0.032~~	~~-0.594~~ ~~21~~ ~~0.002~~	~~0.63~~ ~~21~~ ~~0.001~~	~~0.453~~ ~~21~~ ~~0.019~~	~~0.068~~ ~~21~~ ~~0.382~~	~~0.228~~ ~~21~~ ~~0.161~~	1	0.569 21 0.004	0.587 21 0.002	0.575 21 0.003	0.61 21 0.002	-0.01 21 0.458
CO_2	~~0.009~~ ~~21~~ ~~0.46~~	~~0.148~~ ~~21~~ ~~0.264~~	~~0.101~~ ~~30~~ ~~0.3~~	~~0.318~~ ~~21~~ ~~0.079~~	~~-0.579~~ ~~21~~ ~~0.003~~	~~0.373~~ ~~30~~ ~~0.021~~	~~0.134~~ ~~21~~ ~~0.284~~	~~0.113~~ ~~21~~ ~~0.315~~	~~-0.183~~ ~~30~~ ~~0.168~~	~~0.569~~ ~~21~~ ~~0.004~~	1	0.332 30 0.035	0.495 21 0.011	0.466 21 0.016	-0.401 21 0.034
cond.	~~0.203~~ ~~21~~ ~~0.191~~	~~0.647~~ ~~21~~ ~~0.001~~	~~0.482~~ ~~30~~ ~~0.004~~	~~0.853~~ ~~21~~ ~~0~~	~~-0.834~~ ~~21~~ ~~0~~	~~0.975~~ ~~30~~ ~~0~~	~~-0.014~~ ~~21~~ ~~0.454~~	~~0.068~~ ~~21~~ ~~0.382~~	~~0.649~~ ~~30~~ ~~0~~	~~0.587~~ ~~21~~ ~~0.002~~	~~0.332~~ ~~30~~ ~~0.035~~	1	0.712 21 0	0.026 21 0.438	0.311 21 0.083
Cr	~~0.156~~ ~~21~~ ~~0.253~~	~~0.417~~ ~~21~~ ~~0.029~~	~~0.457~~ ~~21~~ ~~0.018~~	~~0.603~~ ~~21~~ ~~0.002~~	~~-0.614~~ ~~21~~ ~~0.002~~	~~0.698~~ ~~21~~ ~~0~~	~~0.204~~ ~~21~~ ~~0.19~~	~~-0.09~~ ~~21~~ ~~0.35~~	~~0.234~~ ~~21~~ ~~0.154~~	~~0.575~~ ~~21~~ ~~0.003~~	~~0.495~~ ~~21~~ ~~0.011~~	~~0.712~~ ~~21~~ ~~0~~	1	0.162 21 0.244	-0.006 21 0.463
Cu	~~0.203~~ ~~21~~ ~~0.191~~	~~0.191~~ ~~21~~ ~~0.206~~	~~0.212~~ ~~21~~ ~~0.18~~	~~-0.119~~ ~~21~~ ~~0.306~~	~~-0.151~~ ~~21~~ ~~0.261~~	~~0.058~~ ~~21~~ ~~0.396~~	~~0.474~~ ~~21~~ ~~0.014~~	~~0.236~~ ~~21~~ ~~0.152~~	~~0.066~~ ~~21~~ ~~0.384~~	~~0.61~~ ~~21~~ ~~0.002~~	~~0.466~~ ~~21~~ ~~0.016~~	~~0.026~~ ~~21~~ ~~0.438~~	~~0.162~~ ~~21~~ ~~0.244~~	1	-0.219 21 0.171
$\delta^{18}O$	~~0.479~~ ~~21~~ ~~0.014~~	~~0.528~~ ~~21~~ ~~0.007~~	~~0.294~~ ~~21~~ ~~0.097~~	~~0.266~~ ~~21~~ ~~0.122~~	~~-0.068~~ ~~21~~ ~~0.382~~	~~0.308~~ ~~21~~ ~~0.086~~	~~-0.027~~ ~~21~~ ~~0.437~~	~~0.335~~ ~~21~~ ~~0.067~~	~~0.612~~ ~~21~~ ~~0.002~~	~~-0.01~~ ~~21~~ ~~0.458~~	~~-0.401~~ ~~21~~ ~~0.034~~	~~0.311~~ ~~21~~ ~~0.083~~	~~-0.006~~ ~~21~~ ~~0.463~~	~~-0.219~~ ~~21~~ ~~0.171~~	1

	δ^2H	Dy	EH	Er	Eu	F	Fe	Gd	GW table	HCO_3	Ho	K	La	Li	Lu
Al	0.332 21 0.069	0.444 21 0.021	0.182 16 0.252	0.303 21 0.09	0.236 21 0.152	0.287 21 0.102	0.153 21 0.257	0.44 21 0.022	-0.145 20 0.274	-0.312 21 0.083	0.012 21 0.456	0.317 21 0.079	0.803 21 0	0.195 21 0.201	0.097 21 0.338
As	0.403 21 0.034	0.186 21 0.213	-0.212 16 0.218	-0.11 21 0.319	0.021 21 0.445	0.675 21 0.001	0.261 21 0.126	-0.027 21 0.437	-0.21 20 0.189	-0.368 21 0.049	0.013 21 0.455	0.68 21 0.001	0.226 21 0.163	0.668 21 0.001	0.094 21 0.344
As ICP	0.122 21 0.301	-0.027 21 0.437	0.171 22 0.226	0.04 21 0.419	-0.031 21 0.431	0.471 30 0.004	0.029 21 0.435	0.048 21 0.409	-0.121 27 0.277	-0.06 30 0.373	0.192 21 0.204	0.376 30 0.019	-0.013 21 0.455	0.53 21 0.007	-0.025 21 0.44
B	0.302 21 0.09	0.288 21 0.101	0.135 16 0.311	0.062 21 0.389	-0.049 21 0.407	0.832 21 0	0.131 21 0.289	0.147 21 0.266	-0.152 20 0.264	-0.443 21 0.021	0.388 21 0.04	0.771 21 0	-0.081 21 0.363	0.91 21 0	0.095 21 0.342
Ba	-0.021 21 0.444	0.008 21 0.462	0.174 16 0.263	-0.055 21 0.4	0.173 21 0.23	-0.789 21 0	-0.142 21 0.273	0.095 21 0.342	0.425 20 0.03	0.043 21 0.416	-0.16 21 0.248	-0.456 21 0.018	0.33 21 0.071	-0.8 21 0	0.105 21 0.327
Ca	0.276 21 0.112	0.216 21 0.175	0.053 22 0.4	0.065 21 0.386	-0.051 21 0.405	0.922 30 0	0.255 21 0.132	0.186 21 0.212	-0.19 27 0.172	-0.252 30 0.087	0.255 21 0.132	0.574 30 0.001	0.046 21 0.412	0.939 21 0	-0.167 21 0.238
Cd	0.035 21 0.426	0.035 21 0.426	-0.018 16 0.452	-0.062 21 0.389	0.217 21 0.174	0.09 21 0.35	0.734 21 0	0.036 21 0.424	-0.257 20 0.137	0.025 21 0.44	-0.21 21 0.182	-0.073 21 0.373	0.334 21 0.068	0.01 21 0.458	-0.182 21 0.218
Ce	0.2 21 0.194	0.405 21 0.033	0.297 16 0.132	0.281 21 0.108	0.174 21 0.228	0.13 21 0.29	0.118 21 0.308	0.351 21 0.058	-0.03 20 0.434	-0.135 21 0.283	0.025 21 0.44	0.117 21 0.31	0.832 21 0	0.052 21 0.403	-0.017 21 0.45

	δ^2H	Dy	EH	Er	Eu	F	Fe	Gd	GW table	HCO_3	Ho	K	La	Li	Lu
Cl	0.439 21 0.022	0.267 21 0.12	0.171 22 0.227	-0.041 21 0.419	-0.085 21 0.356	0.468 30 0.004	-0.069 21 0.38	0.126 21 0.297	0.301 27 0.062	-0.577 30 0.001	0.274 21 0.113	0.857 30 0	0.196 21 0.199	0.666 21 0.001	0.092 21 0.347
Co	-0.092 21 0.347	0.157 21 0.252	-0.003 16 0.47	0.377 21 0.045	-0.051 21 0.405	0.628 21 0.001	0.586 21 0.002	0.366 21 0.049	-0.52 20 0.009	0.074 21 0.373	0.23 21 0.159	0.22 21 0.17	0.201 21 0.192	0.597 21 0.002	0.012 21 0.456
CO_2	-0.505 21 0.009	0.167 21 0.238	-0.155 22 0.248	0.374 21 0.045	-0.211 21 0.181	0.374 30 0.02	0.076 21 0.37	-0.094 21 0.343	-0.719 27 0	0.642 30 0	-0.026 21 0.438	-0.223 30 0.117	0.068 21 0.38	0.442 21 0.022	-0.211 21 0.181
cond.	0.267 21 0.12	0.21 21 0.182	0.018 22 0.449	0.057 21 0.396	-0.071 21 0.376	0.871 30 0	0.175 21 0.227	0.134 21 0.285	-0.204 27 0.154	-0.285 30 0.062	0.255 21 0.132	0.615 30 0	-0.008 21 0.462	0.942 21 0	-0.126 21 0.296
Cr	-0.003 21 0.47	0.09 21 0.35	-0.01 16 0.461	0.277 21 0.112	0.096 21 0.34	0.736 21 0	0.284 21 0.105	0.069 21 0.38	-0.531 20 0.007	0.075 21 0.37	0.034 21 0.428	0.337 21 0.066	-0.051 21 0.405	0.692 21 0.001	-0.073 21 0.374
Cu	-0.382 21 0.042	0.269 21 0.119	-0.177 16 0.259	0.438 21 0.023	0.094 21 0.344	0.125 21 0.298	0.338 21 0.065	0.06 21 0.393	-0.379 20 0.048	0.357 21 0.054	-0.096 21 0.34	-0.049 21 0.407	0.394 21 0.038	0.091 21 0.348	0.074 21 0.373
$\delta^{18}O$	0.915 21 0	0.313 21 0.082	-0.253 16 0.173	-0.263 21 0.124	0.034 21 0.427	0.304 21 0.089	0.118 21 0.308	0.448 21 0.02	0.426 20 0.03	-0.763 21 0	0.244 21 0.143	0.603 21 0.002	0.333 21 0.068	0.328 21 0.072	0.177 21 0.223
δ^2H	1	0.26 21 0.127	-0.247 16 0.179	-0.38 21 0.043	0.097 21 0.338	0.273 21 0.115	0.234 21 0.154	0.402 21 0.034	0.525 20 0.009	-0.825 21 0	0.283 21 0.106	0.51 21 0.009	0.188 21 0.209	0.289 21 0.101	0.134 21 0.285
Dy	~~0.26~~ ~~21~~ ~~0.127~~	1	0.157 16 0.283	0.205 21 0.188	0.369 21 0.049	0.29 21 0.1	0.074 21 0.373	0.491 21 0.012	0.031 20 0.433	-0.271 21 0.116	0.365 21 0.05	0.446 21 0.021	0.561 21 0.004	0.252 21 0.135	0.382 21 0.042
EH	~~-0.247~~ ~~16~~ ~~0.179~~	~~0.157~~ ~~16~~ ~~0.283~~	1	0.193 16 0.24	-0.068 16 0.396	0.144 22 0.264	-0.383 16 0.07	0.433 16 0.045	0.246 19 0.155	-0.212 22 0.173	0.486 16 0.027	0.095 22 0.338	0.383 16 0.07	-0.06 16 0.404	0.084 16 0.375
Er	~~-0.38~~ ~~21~~ ~~0.043~~	~~0.205~~ ~~21~~ ~~0.188~~	~~0.193~~ ~~16~~ ~~0.24~~	1	0.174 21 0.228	0.229 21 0.159	0.016 21 0.451	0.374 21 0.046	-0.225 20 0.171	0.188 21 0.209	0.323 21 0.075	0.054 21 0.401	0.471 21 0.015	0.194 21 0.203	0.284 21 0.105
Eu	~~0.097~~ ~~21~~ ~~0.338~~	~~0.369~~ ~~21~~ ~~0.049~~	~~-0.068~~ ~~16~~ ~~0.396~~	~~0.174~~ ~~21~~ ~~0.228~~	1	0.041 21 0.419	0.314 21 0.081	0.106 21 0.325	0.069 20 0.382	-0.156 21 0.253	-0.026 21 0.438	0.104 21 0.329	0.282 21 0.107	-0.055 21 0.4	-0.061 21 0.391
F	~~0.273~~ ~~21~~ ~~0.115~~	~~0.29~~ ~~21~~ ~~0.1~~	~~0.144~~ ~~22~~ ~~0.264~~	~~0.229~~ ~~21~~ ~~0.159~~	~~0.041~~ ~~21~~ ~~0.419~~	1	0.226 21 0.163	0.214 21 0.176	-0.293 27 0.067	-0.202 30 0.142	0.322 21 0.075	0.517 30 0.002	0.154 21 0.257	0.938 21 0	-0.011 21 0.458
Fe	~~0.234~~ ~~21~~ ~~0.154~~	~~0.074~~ ~~21~~ ~~0.373~~	~~-0.383~~ ~~16~~ ~~0.07~~	~~0.016~~ ~~21~~ ~~0.451~~	~~0.314~~ ~~21~~ ~~0.081~~	~~0.226~~ ~~21~~ ~~0.163~~	1	0.213 21 0.178	-0.235 20 0.16	-0.061 21 0.391	-0.091 21 0.348	0.008 21 0.461	0.166 21 0.239	0.242 21 0.146	-0.118 21 0.308
Gd	~~0.402~~ ~~21~~ ~~0.034~~	~~0.491~~ ~~21~~ ~~0.012~~	~~0.433~~ ~~16~~ ~~0.045~~	~~0.374~~ ~~21~~ ~~0.046~~	~~0.106~~ ~~21~~ ~~0.325~~	~~0.214~~ ~~21~~ ~~0.176~~	~~0.213~~ ~~21~~ ~~0.178~~	1	0.19 20 0.214	-0.455 21 0.019	0.612 21 0.002	0.261 21 0.126	0.526 21 0.007	0.169 21 0.235	0.361 21 0.052
GW table	~~0.525~~ ~~20~~ ~~0.009~~	~~0.031~~ ~~20~~ ~~0.433~~	~~0.246~~ ~~19~~ ~~0.155~~	~~-0.225~~ ~~20~~ ~~0.171~~	~~0.069~~ ~~20~~ ~~0.382~~	~~-0.293~~ ~~27~~ ~~0.067~~	~~-0.235~~ ~~20~~ ~~0.16~~	~~0.19~~ ~~20~~ ~~0.214~~	1	-0.649 27 0	0.416 20 0.032	0.291 27 0.068	-0.018 20 0.449	-0.266 20 0.127	0.263 20 0.132
HCO_3	~~-0.825~~ ~~21~~ ~~0~~	~~-0.271~~ ~~21~~ ~~0.116~~	~~-0.212~~ ~~22~~ ~~0.173~~	~~0.188~~ ~~21~~ ~~0.209~~	~~-0.156~~ ~~21~~ ~~0.253~~	~~-0.202~~ ~~30~~ ~~0.142~~	~~-0.061~~ ~~21~~ ~~0.391~~	~~-0.455~~ ~~21~~ ~~0.019~~	~~-0.649~~ ~~27~~ ~~0~~	1	-0.471 21 0.015	-0.722 30 0	-0.247 21 0.14	-0.318 21 0.079	-0.27 21 0.117
Ho	~~0.283~~ ~~21~~ ~~0.106~~	~~0.365~~ ~~21~~ ~~0.05~~	~~0.486~~ ~~16~~ ~~0.027~~	~~0.323~~ ~~21~~ ~~0.075~~	~~-0.026~~ ~~21~~ ~~0.438~~	~~0.322~~ ~~21~~ ~~0.075~~	~~-0.091~~ ~~21~~ ~~0.348~~	~~0.612~~ ~~21~~ ~~0.002~~	~~0.416~~ ~~20~~ ~~0.032~~	~~-0.471~~ ~~21~~ ~~0.015~~	1	0.421 21 0.027	0.171 21 0.231	0.339 21 0.064	0.57 21 0.004
K	~~0.51~~ ~~21~~ ~~0.009~~	~~0.446~~ ~~21~~ ~~0.021~~	~~0.095~~ ~~22~~ ~~0.338~~	~~0.054~~ ~~21~~ ~~0.401~~	~~0.104~~ ~~21~~ ~~0.329~~	~~0.517~~ ~~30~~ ~~0.002~~	~~0.008~~ ~~21~~ ~~0.461~~	~~0.261~~ ~~21~~ ~~0.126~~	~~0.291~~ ~~27~~ ~~0.068~~	~~-0.722~~ ~~30~~ ~~0~~	~~0.421~~ ~~21~~ ~~0.027~~	1	0.235 21 0.154	0.74 21 0	0.279 21 0.109
La	~~0.188~~ ~~21~~ ~~0.209~~	~~0.561~~ ~~21~~ ~~0.004~~	~~0.383~~ ~~16~~ ~~0.07~~	~~0.471~~ ~~21~~ ~~0.015~~	~~0.282~~ ~~21~~ ~~0.107~~	~~0.154~~ ~~21~~ ~~0.257~~	~~0.166~~ ~~21~~ ~~0.239~~	~~0.526~~ ~~21~~ ~~0.007~~	~~-0.018~~ ~~20~~ ~~0.449~~	~~-0.247~~ ~~21~~ ~~0.14~~	~~0.171~~ ~~21~~ ~~0.231~~	~~0.235~~ ~~21~~ ~~0.154~~	1	0.038 21 0.423	0.122 21 0.302
Li	~~0.289~~ ~~21~~ ~~0.101~~	~~0.252~~ ~~21~~ ~~0.135~~	~~-0.06~~ ~~16~~ ~~0.404~~	~~0.194~~ ~~21~~ ~~0.203~~	~~-0.055~~ ~~21~~ ~~0.4~~	~~0.938~~ ~~21~~ ~~0~~	~~0.242~~ ~~21~~ ~~0.146~~	~~0.169~~ ~~21~~ ~~0.235~~	~~-0.266~~ ~~20~~ ~~0.127~~	~~-0.318~~ ~~21~~ ~~0.079~~	~~0.339~~ ~~21~~ ~~0.064~~	~~0.74~~ ~~21~~ ~~0~~	~~0.038~~ ~~21~~ ~~0.423~~	1	0.03 21 0.433
Lu	~~0.134~~ ~~21~~ ~~0.285~~	~~0.382~~ ~~21~~ ~~0.042~~	~~0.084~~ ~~16~~ ~~0.375~~	~~0.284~~ ~~21~~ ~~0.105~~	~~-0.061~~ ~~21~~ ~~0.391~~	~~-0.011~~ ~~21~~ ~~0.458~~	~~-0.118~~ ~~21~~ ~~0.308~~	~~0.361~~ ~~21~~ ~~0.052~~	~~0.263~~ ~~20~~ ~~0.132~~	~~-0.27~~ ~~21~~ ~~0.117~~	~~0.57~~ ~~21~~ ~~0.004~~	~~0.279~~ ~~21~~ ~~0.109~~	~~0.122~~ ~~21~~ ~~0.302~~	~~0.03~~ ~~21~~ ~~0.433~~	1

	Mg	Mn	Na	Nd	Ni	NO_2	NO_3	O_2	Pb	pH	PO_4	Pr	Sb	Sc	Se
Al	0.229 21 0.16	0.632 21 0.001	0.335 21 0.067	0.726 21 0	0.145 21 0.268	-0.146 16 0.298	0.187 21 0.211	-0.172 12 0.299	-0.043 21 0.416	-0.349 21 0.058	0.43 18 0.036	0.769 21 0	-0.144 21 0.27	0.582 21 0.003	0.4 21 0.034
As	0.634 21 0.001	0.518 21 0.007	0.69 21 0.001	0.036 21 0.424	0.618 21 0.002	-0.3 16 0.128	0.145 21 0.268	0.242 12 0.227	-0.218 21 0.172	-0.426 21 0.026	-0.04 18 0.424	0.057 21 0.396	0.171 21 0.231	0.608 21 0.002	0.874 21 0
As ICP	0.321 30 0.04	0.088 21 0.352	0.321 30 0.04	-0.056 21 0.398	0.638 21 0.001	-0.082 22 0.357	0.046 30 0.398	0.093 15 0.368	0.001 21 0.472	0.097 30 0.308	-0.013 24 0.453	-0.082 21 0.361	0.527 21 0.007	0.186 21 0.213	0.491 21 0.012
B	0.853 21 0	0.108 21 0.323	0.7 21 0	-0.266 21 0.121	0.818 21 0	-0.106 16 0.348	-0.217 21 0.174	0.452 12 0.069	-0.378 21 0.044	0.063 21 0.388	-0.26 18 0.148	0.055 21 0.4	0.334 21 0.068	0.157 21 0.252	0.725 21 0

	Mg	Mn	Na	Nd	Ni	NO_2	NO_3	O_2	Pb	pH	PO_4	Pr	Sb	Sc	Se
Ba	-0.821 21 0	0.026 21 0.438	-0.435 21 0.023	0.509 21 0.009	-0.823 21 0	0.134 16 0.313	0.364 21 0.051	-0.361 12 0.124	0.275 21 0.112	-0.068 21 0.38	0.417 18 0.041	0.282 21 0.107	-0.564 21 0.004	-0.018 21 0.449	-0.64 21 0.001
Ca	0.957 30 0	0.292 21 0.098	0.621 30 0	-0.183 21 0.216	0.956 21 0	-0.097 22 0.335	-0.297 30 0.054	0.512 15 0.024	-0.353 21 0.056	-0.064 30 0.368	-0.223 24 0.148	0.099 21 0.336	0.486 21 0.012	0.293 21 0.097	0.873 21 0
Cd	0.06 21 0.391	0.617 21 0.002	-0.01 21 0.458	0.044 21 0.414	0.179 21 0.221	-0.115 16 0.337	-0.069 21 0.38	0.042 12 0.433	0.552 21 0.004	-0.336 21 0.067	-0.051 18 0.411	-0.161 21 0.246	-0.178 21 0.223	0.138 21 0.279	0.232 21 0.156
Ce	0.1 21 0.335	0.612 21 0.002	0.218 21 0.172	0.716 21 0	0.008 21 0.462	-0.077 16 0.384	0.19 21 0.207	-0.144 12 0.329	-0.112 21 0.317	-0.37 21 0.047	0.546 18 0.009	0.645 21 0.001	-0.218 21 0.172	0.584 21 0.002	0.318 21 0.079
Cl	0.535 30 0.001	0.122 21 0.303	0.851 30 0	-0.123 21 0.301	0.613 21 0.002	-0.316 22 0.074	0.389 30 0.016	0.503 15 0.027	-0.319 21 0.078	-0.057 30 0.379	0.046 24 0.406	-0.04 21 0.419	0.274 21 0.114	0.719 21 0	0.743 21 0
Co	0.585 21 0.002	0.456 21 0.018	0.212 21 0.18	0.044 21 0.414	0.729 21 0	-0.108 16 0.346	-0.43 21 0.024	0.011 12 0.462	0.138 21 0.279	-0.112 21 0.317	-0.251 18 0.158	0.091 21 0.348	0.429 21 0.025	0.117 21 0.31	0.506 21 0.009
CO_2	0.381 30 0.018	0.115 21 0.313	-0.107 30 0.289	0.006 21 0.463	0.435 21 0.023	0.046 22 0.41	-0.616 30 0	0.182 15 0.261	-0.039 21 0.421	-0.159 30 0.204	-0.044 24 0.41	0.015 21 0.452	0.442 21 0.022	0.04 21 0.421	0.385 21 0.041
cond.	0.945 30 0	0.225 21 0.164	0.659 30 0	-0.2 21 0.194	0.935 21 0	-0.058 22 0.394	-0.23 30 0.11	0.483 15 0.033	-0.358 21 0.054	-0.05 30 0.391	-0.219 24 0.153	0.108 21 0.323	0.53 21 0.007	0.264 21 0.123	0.861 21 0
Cr	0.699 21 0	0.117 21 0.31	0.268 21 0.12	-0.079 21 0.365	0.682 21 0.001	-0.283 16 0.145	-0.436 21 0.023	0.21 12 0.259	0.152 21 0.259	-0.172 21 0.231	-0.227 18 0.184	0.084 21 0.357	0.61 21 0.002	0.058 21 0.394	0.558 21 0.004
Cu	0.061 21 0.391	0.371 21 0.047	-0.009 21 0.46	0.256 21 0.131	0.161 21 0.246	-0.274 16 0.153	-0.214 21 0.177	-0.151 12 0.322	0.395 21 0.037	-0.494 21 0.011	-0.243 18 0.167	0.005 21 0.465	0.204 21 0.19	0.3 21 0.092	0.181 21 0.22
$\delta^{18}O$	0.263 21 0.124	0.307 21 0.086	0.698 21 0	0.033 21 0.429	0.347 21 0.06	-0.341 16 0.097	0.535 21 0.006	0.46 12 0.065	-0.274 21 0.113	0.227 21 0.162	0.215 18 0.198	0.151 21 0.261	-0.094 21 0.343	0.582 21 0.003	0.484 21 0.013
δ^2H	0.254 21 0.133	0.248 21 0.139	0.607 21 0.002	-0.101 21 0.333	0.317 21 0.079	-0.338 16 0.1	0.458 21 0.018	0.519 12 0.041	-0.244 21 0.143	0.299 21 0.093	0.148 18 0.282	0.081 21 0.363	-0.159 21 0.25	0.367 21 0.049	0.4 21 0.035
Dy	0.142 21 0.273	0.379 21 0.043	0.457 21 0.018	0.371 21 0.047	0.203 21 0.191	-0.108 16 0.346	0.039 21 0.421	0.389 12 0.105	-0.105 21 0.327	-0.172 21 0.23	-0.068 18 0.389	0.445 21 0.021	-0.006 21 0.463	0.529 21 0.007	0.34 21 0.064
EH	-0.001 22 0.472	-0.079 16 0.381	-0.013 22 0.454	0.231 16 0.197	0.049 16 0.417	0.012 22 0.456	0.184 22 0.208	0.254 15 0.182	-0.157 16 0.283	-0.023 22 0.442	0.441 22 0.019	0.349 16 0.091	-0.032 16 0.436	0.018 16 0.452	-0.059 16 0.406
Er	0.151 21 0.261	0.032 21 0.43	-0.057 21 0.396	0.505 21 0.009	0.095 21 0.342	-0.253 16 0.173	-0.342 21 0.063	-0.217 12 0.252	0.206 21 0.186	-0.093 21 0.345	0.122 18 0.317	0.456 21 0.018	0.151 21 0.261	0.095 21 0.342	-0.069 21 0.38
Eu	-0.041 21 0.419	0.36 21 0.053	0.022 21 0.444	0.216 21 0.175	-0.061 21 0.391	0.367 16 0.079	-0.086 21 0.356	-0.41 12 0.092	0.209 21 0.183	0.094 21 0.344	-0.318 18 0.098	0.234 21 0.154	-0.21 21 0.182	0.075 21 0.37	0.034 21 0.428
F	0.902 30 0	0.29 21 0.1	0.512 30 0.002	-0.054 21 0.401	0.938 21 0	-0.316 22 0.074	-0.389 30 0.016	0.315 15 0.126	-0.249 21 0.138	-0.096 30 0.31	-0.148 24 0.248	0.208 21 0.184	0.416 21 0.029	0.291 21 0.099	0.832 21 0
Fe	0.279 21 0.109	0.666 21 0.001	0.094 21 0.344	-0.022 21 0.444	0.33 21 0.071	0.053 16 0.412	-0.378 21 0.044	-0.312 12 0.162	0.271 21 0.116	0.051 21 0.405	-0.212 18 0.201	-0.035 21 0.426	-0.1 21 0.335	0.03 21 0.433	0.308 21 0.086
Gd	0.123 21 0.3	0.27 21 0.117	0.242 21 0.146	0.371 21 0.047	0.256 21 0.131	-0.004 16 0.468	0.127 21 0.294	0.207 12 0.262	-0.122 21 0.302	0.196 21 0.2	0.309 18 0.105	0.521 21 0.007	-0.075 21 0.37	0.344 21 0.062	0.125 21 0.298
GW table	-0.22 27 0.135	-0.301 20 0.097	0.325 27 0.047	-0.177 20 0.231	-0.321 20 0.083	-0.303 19 0.103	0.582 27 0.001	0.336 13 0.131	-0.178 20 0.229	0.139 27 0.248	0.162 21 0.245	-0.193 20 0.209	-0.19 20 0.213	0.089 20 0.354	-0.245 20 0.149
HCO_3	-0.266 30 0.076	-0.184 21 0.214	-0.682 30 0	0.061 21 0.391	-0.343 21 0.063	0.377 22 0.04	-0.554 30 0.001	-0.602 15 0.009	0.287 21 0.102	-0.106 30 0.292	-0.104 24 0.317	-0.177 21 0.225	0.292 21 0.098	-0.347 21 0.06	-0.358 21 0.054
Ho	0.203 21 0.191	-0.129 21 0.292	0.33 21 0.071	0.084 21 0.357	0.287 21 0.102	-0.037 16 0.431	0.027 21 0.437	0.515 12 0.042	-0.223 21 0.166	0.219 21 0.171	0.251 18 0.158	0.152 21 0.259	0.144 21 0.27	0.134 21 0.285	0.175 21 0.227
K	0.537 30 0.001	0.166 21 0.238	0.909 30 0	-0.016 21 0.451	0.64 21 0.001	-0.37 22 0.043	0.34 30 0.032	0.498 15 0.029	-0.285 21 0.104	-0.019 30 0.442	-0.041 24 0.414	0.156 21 0.253	0.088 21 0.352	0.608 21 0.002	0.717 21 0
La	0.021 21 0.444	0.581 21 0.003	0.271 21 0.116	0.761 21 0	0.057 21 0.396	-0.218 16 0.211	0.244 21 0.143	0.063 12 0.412	0.231 21 0.157	-0.273 21 0.115	0.435 18 0.034	0.647 21 0.001	-0.261 21 0.126	0.603 21 0.002	0.191 21 0.206
Li	0.943 21 0	0.229 21 0.16	0.714 21 0	-0.153 21 0.257	0.922 21 0	-0.261 16 0.166	-0.277 21 0.112	0.322 12 0.154	-0.335 21 0.067	-0.025 21 0.44	-0.244 18 0.166	0.096 21 0.34	0.483 21 0.013	0.295 21 0.096	0.844 21 0
Lu	-0.17 21 0.234	-0.016 21 0.451	0.162 21 0.244	0.214 21 0.177	-0.095 21 0.342	-0.233 16 0.194	0.166 21 0.239	0.046 12 0.43	-0.1 21 0.335	-0.112 21 0.317	0.129 18 0.308	0.131 21 0.289	-0.045 21 0.412	0.162 21 0.244	-0.036 21 0.424
Mg	1	0.264 21 0.123	0.594 30 0.001	-0.213 21 0.178	0.917 21 0	-0.15 22 0.256	-0.327 30 0.037	0.353 15 0.097	-0.355 21 0.056	-0.052 30 0.388	-0.213 24 0.16	0.105 21 0.326	0.422 21 0.027	0.231 21 0.158	0.841 21 0

	Mg	Mn	Na	Nd	Ni	NO_2	NO_3	O_2	Pb	pH	PO_4	Pr	Sb	Sc	Se
Mn	~~0.264~~ ~~21~~ ~~0.123~~	1	0.225 21 0.164	0.369 21 0.049	0.304 21 0.089	0.208 16 0.222	-0.044 21 0.414	-0.315 12 0.16	0.009 21 0.46	-0.285 21 0.105	-0.061 18 0.398	0.383 21 0.041	-0.175 21 0.227	0.325 21 0.074	0.483 21 0.013
Na	~~0.594~~ ~~30~~ ~~0.001~~	~~0.225~~ ~~21~~ ~~0.164~~	1	-0.099 21 0.336	0.635 21 0.001	-0.309 22 0.079	0.291 30 0.058	0.554 15 0.015	-0.288 21 0.101	-0.028 30 0.428	-0.075 24 0.362	0.056 21 0.398	0.125 21 0.298	0.706 21 0	0.764 21 0
Nd	~~-0.213~~ ~~21~~ ~~0.178~~	~~0.369~~ ~~21~~ ~~0.049~~	~~-0.099~~ ~~21~~ ~~0.336~~	1	-0.23 21 0.159	-0.028 16 0.441	0.006 21 0.463	-0.291 12 0.181	0.196 21 0.199	-0.335 21 0.068	0.344 18 0.079	0.832 21 0	-0.26 21 0.127	0.313 21 0.082	-0.095 21 0.342
Ni	~~0.917~~ ~~21~~ ~~0~~	~~0.304~~ ~~21~~ ~~0.089~~	~~0.635~~ ~~21~~ ~~0.001~~	~~-0.23~~ ~~21~~ ~~0.159~~	1	-0.183 16 0.252	-0.166 21 0.239	0.525 12 0.038	-0.239 21 0.148	0.008 21 0.461	-0.283 18 0.127	0.042 21 0.417	0.468 21 0.015	0.242 21 0.146	0.812 21 0
NO_2	~~-0.15~~ ~~22~~ ~~0.256~~	~~0.208~~ ~~16~~ ~~0.222~~	~~-0.309~~ ~~22~~ ~~0.079~~	~~-0.028~~ ~~16~~ ~~0.441~~	~~-0.183~~ ~~16~~ ~~0.252~~	1	0.005 22 0.466	-0.466 15 0.039	-0.272 16 0.154	0.109 22 0.317	-0.149 22 0.257	0.113 16 0.339	-0.153 16 0.289	-0.452 16 0.038	-0.128 16 0.32
NO_3	~~-0.327~~ ~~30~~ ~~0.037~~	~~-0.044~~ ~~21~~ ~~0.414~~	~~0.291~~ ~~30~~ ~~0.058~~	~~0.006~~ ~~21~~ ~~0.463~~	~~-0.166~~ ~~21~~ ~~0.239~~	~~0.005~~ ~~22~~ ~~0.466~~	1	0.341 15 0.105	-0.078 21 0.366	-0.104 30 0.296	0.256 24 0.113	-0.03 21 0.433	-0.318 21 0.079	0.43 21 0.024	-0.044 21 0.414
O_2	~~0.353~~ ~~15~~ ~~0.097~~	~~-0.315~~ ~~12~~ ~~0.16~~	~~0.554~~ ~~15~~ ~~0.015~~	~~-0.291~~ ~~12~~ ~~0.181~~	~~0.525~~ ~~12~~ ~~0.038~~	~~-0.466~~ ~~15~~ ~~0.039~~	~~0.341~~ ~~15~~ ~~0.105~~	1	-0.137 12 0.337	0.168 15 0.278	-0.03 15 0.44	-0.315 12 0.16	-0.007 12 0.465	0.396 12 0.101	0.434 12 0.078
Pb	~~-0.355~~ ~~21~~ ~~0.056~~	~~0.009~~ ~~21~~ ~~0.46~~	~~-0.288~~ ~~21~~ ~~0.101~~	~~0.196~~ ~~21~~ ~~0.199~~	~~-0.239~~ ~~21~~ ~~0.148~~	~~-0.272~~ ~~16~~ ~~0.154~~	~~-0.078~~ ~~21~~ ~~0.366~~	~~-0.137~~ ~~12~~ ~~0.337~~	1	-0.062 21 0.39	-0.042 18 0.421	-0.11 21 0.319	0.017 21 0.45	-0.116 21 0.312	-0.351 21 0.058
pH	~~-0.052~~ ~~30~~ ~~0.388~~	~~-0.285~~ ~~21~~ ~~0.105~~	~~-0.028~~ ~~30~~ ~~0.428~~	~~-0.335~~ ~~21~~ ~~0.068~~	~~0.008~~ ~~21~~ ~~0.461~~	~~0.109~~ ~~22~~ ~~0.317~~	~~-0.104~~ ~~30~~ ~~0.296~~	~~0.168~~ ~~15~~ ~~0.278~~	~~-0.062~~ ~~21~~ ~~0.39~~	1	0.008 24 0.461	-0.154 21 0.256	-0.049 21 0.407	-0.341 21 0.064	-0.284 21 0.105
PO_4	~~-0.213~~ ~~24~~ ~~0.16~~	~~-0.061~~ ~~18~~ ~~0.398~~	~~-0.075~~ ~~24~~ ~~0.362~~	~~0.344~~ ~~18~~ ~~0.079~~	~~-0.283~~ ~~18~~ ~~0.127~~	~~-0.149~~ ~~22~~ ~~0.257~~	~~0.256~~ ~~24~~ ~~0.113~~	~~-0.03~~ ~~15~~ ~~0.44~~	~~-0.042~~ ~~18~~ ~~0.421~~	~~0.008~~ ~~24~~ ~~0.461~~	1	0.241 18 0.169	-0.211 18 0.203	0.267 18 0.142	-0.07 18 0.386
Pr	~~0.105~~ ~~21~~ ~~0.326~~	~~0.383~~ ~~21~~ ~~0.041~~	~~0.056~~ ~~21~~ ~~0.398~~	~~0.832~~ ~~21~~ ~~0~~	~~0.042~~ ~~21~~ ~~0.417~~	~~0.113~~ ~~16~~ ~~0.339~~	~~-0.03~~ ~~21~~ ~~0.433~~	~~-0.315~~ ~~12~~ ~~0.16~~	~~-0.11~~ ~~21~~ ~~0.319~~	~~-0.154~~ ~~21~~ ~~0.256~~	~~0.241~~ ~~18~~ ~~0.169~~	1	-0.152 21 0.259	0.212 21 0.18	0.052 21 0.403
Sb	~~0.422~~ ~~21~~ ~~0.027~~	~~-0.175~~ ~~21~~ ~~0.227~~	~~0.125~~ ~~21~~ ~~0.298~~	~~-0.26~~ ~~21~~ ~~0.127~~	~~0.468~~ ~~21~~ ~~0.015~~	~~-0.153~~ ~~16~~ ~~0.289~~	~~-0.318~~ ~~21~~ ~~0.079~~	~~-0.007~~ ~~12~~ ~~0.465~~	~~0.017~~ ~~21~~ ~~0.45~~	~~-0.049~~ ~~21~~ ~~0.407~~	~~-0.211~~ ~~18~~ ~~0.203~~	~~-0.152~~ ~~21~~ ~~0.259~~	1	-0.065 21 0.386	0.323 21 0.075
Sc	~~0.231~~ ~~21~~ ~~0.158~~	~~0.325~~ ~~21~~ ~~0.074~~	~~0.706~~ ~~21~~ ~~0~~	~~0.313~~ ~~21~~ ~~0.082~~	~~0.242~~ ~~21~~ ~~0.146~~	~~-0.452~~ ~~16~~ ~~0.038~~	~~0.43~~ ~~21~~ ~~0.024~~	~~0.396~~ ~~12~~ ~~0.101~~	~~-0.116~~ ~~21~~ ~~0.312~~	~~-0.341~~ ~~21~~ ~~0.064~~	~~0.267~~ ~~18~~ ~~0.142~~	~~0.212~~ ~~21~~ ~~0.18~~	~~-0.065~~ ~~21~~ ~~0.386~~	1	0.571 21 0.004
Se	~~0.841~~ ~~21~~ ~~0~~	~~0.483~~ ~~21~~ ~~0.013~~	~~0.764~~ ~~21~~ ~~0~~	~~-0.095~~ ~~21~~ ~~0.342~~	~~0.812~~ ~~21~~ ~~0~~	~~-0.128~~ ~~16~~ ~~0.32~~	~~-0.044~~ ~~21~~ ~~0.414~~	~~0.434~~ ~~12~~ ~~0.078~~	~~-0.351~~ ~~21~~ ~~0.058~~	~~-0.284~~ ~~21~~ ~~0.105~~	~~-0.07~~ ~~18~~ ~~0.386~~	~~0.052~~ ~~21~~ ~~0.403~~	~~0.323~~ ~~21~~ ~~0.075~~	~~0.571~~ ~~21~~ ~~0.004~~	1

	SiO_2	Sm	SO_4	Sr	T.U.	Tb	temp.	Th	Tl	Tm	U	Y	Yb	Zn
Al	0.14 21 0.27	0.452 21 0.019	0.165 21 0.241	0.212 21 0.18	-0.25 20 0.145	0.395 21 0.037	-0.136 21 0.282	0.496 21 0.01	-0.127 21 0.29	0.06 21 0.393	0.53 21 0.007	0.532 21 0.007	0.37 21 0.047	0.; 21 0.034
As	0.097 21 0.338	-0.09 21 0.35	0.614 21 0.002	0.677 21 0.001	-0.424 20 0.03	0.052 21 0.403	-0.224 21 0.166	0.206 21 0.186	0.483 21 0.013	-0.008 21 0.462	0.765 21 0	0.292 21 0.098	0.258 21 0.128	-0.025 21 0.44
As ICP	-0.1 30 0.303	-0.149 21 0.262	0.463 30 0.005	0.638 21 0.001	0.039 20 0.423	0.243 21 0.145	-0.168 30 0.189	-0.294 21 0.097	0.523 21 0.007	0.212 21 0.18	0.322 21 0.075	0.127 21 0.294	0.251 21 0.137	-0.271 21 0.116
B	-0.056 21 0.398	-0.048 21 0.409	0.857 21 0	0.848 21 0	-0.281 20 0.114	-0.117 21 0.31	-0.267 21 0.12	-0.139 21 0.278	0.634 21 0.001	0.078 21 0.366	0.453 21 0.019	0.145 21 0.268	0.425 21 0.026	-0.309 21 0.085
Ba	0.388 21 0.04	0.396 21 0.036	-0.862 21 0	-0.818 21 0	0.056 20 0.4	0.314 21 0.081	0.043 21 0.416	0.531 21 0.007	-0.709 21 0	-0.053 21 0.401	-0.273 21 0.115	-0.029 21 0.435	-0.161 21 0.246	0.514 21 0.008
Ca	-0.228 30 0.112	-0.12 21 0.306	0.975 30 0	0.956 21 0	-0.305 20 0.094	-0.055 21 0.399	-0.082 30 0.335	-0.242 21 0.145	0.663 21 0.001	-0.011 21 0.458	0.574 21 0.003	0.231 21 0.158	0.298 21 0.094	-0.287 21 0.102
Cd	0.001 21 0.472	0.169 21 0.235	0.027 21 0.437	0.038 21 0.423	-0.349 20 0.064	-0.112 21 0.317	0.059 21 0.394	0.119 21 0.306	-0.308 21 0.086	-0.132 21 0.287	0.143 21 0.271	0.249 21 0.138	-0.009 21 0.46	0.24 21 0.147
Ce	0.155 21 0.255	0.509 21 0.009	0.014 21 0.454	0.051 21 0.405	-0.147 20 0.271	0.406 21 0.032	-0.028 21 0.435	0.505 21 0.009	-0.206 21 0.186	-0.071 21 0.376	0.458 21 0.018	0.556 21 0.004	0.2 21 0.194	0.406 21 0.032
Cl	0.398 30 0.014	-0.047 21 0.41	0.616 30 0	0.639 21 0.001	-0.169 20 0.241	0.232 21 0.157	-0.561 30 0.001	-0.064 21 0.386	0.443 21 0.021	0.012 21 0.456	0.779 21 0	0.331 21 0.069	0.347 21 0.06	-0.15 21 0.262
Co	-0.494 21 0.011	0.097 21 0.338	0.603 21 0.002	0.634 21 0.001	-0.317 20 0.085	-0.164 21 0.243	0.084 21 0.357	-0.297 21 0.094	0.322 21 0.075	0.142 21 0.273	0.196 21 0.199	0.46 21 0.017	0.388 21 0.04	-0.042 21 0.417
CO_2	-0.605 30 0	-0.225 21 0.164	0.338 30 0.032	0.44 21 0.022	0.092 20 0.35	-0.11 21 0.32	0.567 30 0.001	-0.241 21 0.147	0.379 21 0.043	-0.106 21 0.326	0.147 21 0.265	0.276 21 0.112	-0.008 21 0.461	-0.53 21 0.007
cond.	-0.178 30 0.175	-0.187 21 0.211	0.982 30 0	0.96 21 0	-0.277 20 0.118	-0.086 21 0.356	-0.165 30 0.194	-0.283 21 0.105	0.687 21 0.001	0.006 21 0.463	0.544 21 0.005	0.216 21 0.175	0.305 21 0.088	-0.33 21 0.071

	SiO_2	Sm	SO_4	Sr	T.U.	Tb	temp.	Th	Tl	Tm	U	Y	Yb	Zn
Cr	-0.426 21 0.026	-0.268 21 0.12	0.706 21 0	0.716 21 0	-0.275 20 0.119	0.027 21 0.437	0.29 21 0.1	-0.221 21 0.169	0.54 21 0.005	0.014 21 0.454	0.305 21 0.088	0.044 21 0.414	0.243 21 0.145	-0.392 21 0.038
Cu	-0.394 21 0.038	0.203 21 0.191	0.055 21 0.4	0.073 21 0.374	-0.036 20 0.426	0.121 21 0.304	0.255 21 0.132	-0.119 21 0.306	0.005 21 0.465	-0.143 21 0.271	0.234 21 0.154	0.592 21 0.002	0.11 21 0.319	-0.051 21 0.405
$\delta^{18}O$	0.629 21 0.001	0.118 21 0.308	0.294 21 0.097	0.333 21 0.068	-0.268 20 0.126	0.119 21 0.306	-0.721 21 0	0.372 21 0.047	0.048 21 0.409	0.266 21 0.122	0.583 21 0.002	0.02 21 0.445	0.342 21 0.063	0.285 21 0.105
$\delta^{2}H$	0.595 21 0.002	0.11 21 0.319	0.268 21 0.119	0.273 21 0.115	-0.404 20 0.037	-0.014 21 0.453	-0.717 21 0	0.328 21 0.072	0.03 21 0.433	0.198 21 0.198	0.426 21 0.026	-0.117 21 0.31	0.224 21 0.166	0.312 21 0.083
Dy	0.153 21 0.257	0.317 21 0.079	0.17 21 0.234	0.161 21 0.246	-0.329 20 0.076	0.238 21 0.15	-0.26 21 0.127	0.378 21 0.044	0.091 21 0.348	-0.162 21 0.244	0.37 21 0.047	0.53 21 0.007	0.323 21 0.075	0.094 21 0.344
EH	-0.029 22 0.433	0.316 16 0.116	-0.011 22 0.458	0.044 16 0.423	0.029 15 0.442	0.231 16 0.197	-0.123 22 0.296	0.037 16 0.431	-0.213 16 0.216	-0.113 16 0.339	-0.015 16 0.456	0.2 16 0.231	0.112 16 0.34	0.084 16 0.375
Er	-0.31 21 0.084	0.348 21 0.06	0.055 21 0.4	0.177 21 0.225	-0.03 20 0.434	0.399 21 0.035	0.183 21 0.216	-0.04 21 0.419	0.134 21 0.285	0.338 21 0.065	-0.058 21 0.394	0.482 21 0.013	0.442 21 0.022	0.082 21 0.361
Eu	-0.018 21 0.449	0.39 21 0.039	-0.048 21 0.409	-0.045 21 0.412	-0.212 20 0.186	0.269 21 0.119	-0.17 21 0.233	0.113 21 0.315	-0.144 21 0.27	-0.277 21 0.112	-0.043 21 0.416	0.248 21 0.139	0.184 21 0.214	0.465 21 0.016
F	-0.323 30 0.039	-0.075 21 0.37	0.898 30 0	0.963 21 0	-0.33 20 0.076	0.052 21 0.404	-0.007 30 0.46	-0.187 21 0.211	0.69 21 0.001	0.135 21 0.282	0.541 21 0.005	0.32 21 0.077	0.376 21 0.045	-0.276 21 0.112
Fe	-0.156 21 0.253	0.231 21 0.157	0.238 21 0.15	0.209 21 0.183	-0.54 20 0.007	-0.344 21 0.062	-0.062 21 0.389	0.018 21 0.449	-0.071 21 0.376	-0.019 21 0.447	0.07 21 0.378	0.238 21 0.15	0.188 21 0.209	0.413 21 0.03
Gd	0.184 21 0.214	0.468 21 0.015	0.109 21 0.321	0.178 21 0.223	-0.344 20 0.067	0.139 21 0.278	-0.407 21 0.032	0.306 21 0.087	-0.134 21 0.285	0.348 21 0.06	0.116 21 0.312	0.334 21 0.068	0.613 21 0.002	0.427 21 0.025
GW table	0.668 27 0	0.261 20 0.133	-0.212 27 0.144	-0.337 20 0.072	-0.04 19 0.424	0.141 20 0.279	-0.625 27 0.001	0.254 20 0.14	-0.229 20 0.166	0.033 20 0.43	-0.012 20 0.456	-0.295 20 0.102	0.045 20 0.414	0.363 20 0.056
HCO_3	-0.681 30 0	-0.319 21 0.078	-0.271 30 0.072	-0.316 21 0.08	0.293 20 0.104	-0.065 21 0.386	0.815 30 0	-0.205 21 0.188	0.021 21 0.445	-0.223 21 0.166	-0.351 21 0.058	-0.129 21 0.292	-0.438 21 0.023	-0.356 21 0.055
Ho	0.192 21 0.204	0.317 21 0.079	0.204 21 0.19	0.29 21 0.1	-0.299 20 0.098	0.099 21 0.336	-0.384 21 0.041	0.149 21 0.262	0.204 21 0.19	0.361 21 0.052	-0.035 21 0.426	0.234 21 0.154	0.627 21 0.001	0.121 21 0.304
K	0.491 30 0.003	0.079 21 0.366	0.598 30 0.001	0.688 21 0.001	-0.299 20 0.099	0.231 21 0.157	-0.631 30 0	0.094 21 0.344	0.459 21 0.018	0.183 21 0.216	0.686 21 0.001	0.394 21 0.037	0.572 21 0.004	-0.075 21 0.37
La	0.244 21 0.143	0.542 21 0.005	-0.036 21 0.424	0.055 21 0.4	-0.182 20 0.224	0.543 21 0.005	-0.208 21 0.184	0.442 21 0.022	-0.284 21 0.105	0.164 21 0.243	0.394 21 0.038	0.682 21 0.001	0.321 21 0.076	0.438 21 0.023
Li	-0.199 21 0.196	-0.096 21 0.34	0.936 21 0	0.966 21 0	-0.362 20 0.056	-0.029 21 0.435	-0.168 21 0.237	-0.168 21 0.237	0.762 21 0	0.143 21 0.271	0.583 21 0.002	0.238 21 0.15	0.413 21 0.03	-0.282 21 0.107
Lu	0.292 21 0.098	0.321 21 0.076	-0.186 21 0.213	-0.071 21 0.376	-0.203 20 0.198	0.034 21 0.428	-0.258 21 0.129	0.397 21 0.036	0.091 21 0.348	0.232 21 0.156	-0.082 21 0.361	0.188 21 0.209	0.517 21 0.008	0.129 21 0.292
Mg	-0.235 30 0.105	-0.133 21 0.285	0.968 30 0	0.947 21 0	-0.314 20 0.087	-0.141 21 0.275	-0.1 30 0.302	-0.27 21 0.117	0.65 21 0.001	0.039 21 0.421	0.533 21 0.006	0.213 21 0.178	0.296 21 0.094	-0.261 21 0.126
Mn	-0.006 21 0.463	0.447 21 0.02	0.226 21 0.163	0.253 21 0.134	-0.414 20 0.034	-0.101 21 0.333	-0.173 21 0.229	0.31 21 0.084	-0.129 21 0.292	-0.188 21 0.209	0.317 21 0.079	0.475 21 0.014	0.199 21 0.196	0.551 21 0.004
Na	0.487 30 0.003	0.027 21 0.437	0.654 30 0	0.644 21 0.001	-0.326 20 0.079	0.151 21 0.261	-0.623 30 0	0.071 21 0.376	0.388 21 0.04	0.066 21 0.384	0.779 21 0	0.358 21 0.054	0.426 21 0.026	-0.06 21 0.393
Nd	-0.048 21 0.409	0.497 21 0.01	-0.274 21 0.114	-0.143 21 0.271	-0.098 20 0.342	0.634 21 0.001	0.193 21 0.203	0.534 21 0.006	-0.174 21 0.228	0.266 21 0.121	0.134 21 0.285	0.587 21 0.002	0.305 21 0.088	0.358 21 0.054
Ni	-0.244 21 0.143	-0.096 21 0.34	0.943 21 0	0.957 21 0	-0.31 20 0.09	-0.09 21 0.35	-0.225 21 0.164	-0.312 21 0.083	0.631 21 0.001	0.106 21 0.325	0.522 21 0.007	0.226 21 0.163	0.321 21 0.076	-0.255 21 0.132
NO_2	-0.234 22 0.147	0.214 16 0.216	-0.062 22 0.387	-0.165 16 0.274	0.254 15 0.182	-0.399 16 0.061	-0.085 22 0.354	-0.292 16 0.137	-0.321 16 0.112	-0.367 16 0.079	-0.51 16 0.021	0.062 16 0.402	0.103 16 0.352	0.493 16 0.025
NO_3	0.733 30 0	0.135 21 0.283	-0.277 30 0.068	-0.219 21 0.17	0.146 20 0.273	0.306 21 0.087	-0.654 30 0	0.183 21 0.216	-0.334 21 0.068	-0.052 21 0.403	0.284 21 0.105	-0.019 21 0.447	-0.073 21 0.374	0.177 21 0.225
O_2	0.69 15 0.002	-0.175 12 0.296	0.381 15 0.079	0.371 12 0.117	0.231 12 0.237	0.35 12 0.132	-0.219 15 0.219	0.102 12 0.373	0.371 12 0.117	0.203 12 0.266	0.501 12 0.047	-0.063 12 0.412	-0.014 12 0.459	-0.753 12 0.002
Pb	-0.043 21 0.416	-0.052 21 0.403	-0.319 21 0.078	-0.294 21 0.097	-0.044 20 0.417	0.243 21 0.145	0.244 21 0.143	-0.125 21 0	-0.384 21 0.041	0.13 21 0.29	-0.219 21 0	0.114 21 0.313	-0.123 21 0.3	0.058 21 0.394

	SiO_2	Sm	SO_4	Sr	T.U.	Tb	temp.	Th	Tl	Tm	U	Y	Yb	Zn
pH	0.133 30 0.246	0.031 21 0.433	-0.02 30 0.441	-0.019 21 0.447	0.195 20 0.207	-0.164 21 0.242	-0.195 30 0.152	-0.318 21 0.079	-0.117 21 0.31	0.33 21 0.071	-0.38 21 0.043	-0.307 21 0.086	0.156 21 0.253	0.21 21 0.182
PO_4	0.444 24 0.014	0.06 18 0.4	-0.265 24 0.104	-0.211 18 0.203	-0.093 17 0.36	0.14 18 0.292	0.017 24 0.448	0.513 18 0.014	-0.456 18 0.027	0.304 18 0.109	0.029 18 0.438	0.021 18 0.447	0.085 18 0.367	0.26 18 0.148
Pr	-0.14 21 0.275	0.442 21 0.022	0.053 21 0.401	0.129 21 0.292	-0.194 20 0.208	0.435 21 0.023	-0.002 21 0.47	0.342 21 0.063	-0.009 21 0.46	0.201 21 0.192	0.151 21 0.261	0.5 21 0.01	0.316 21 0.08	0.358 21 0.054
Sb	-0.438 21 0.023	-0.469 21 0.015	0.509 21 0.009	0.512 21 0.009	-0.165 20 0.246	-0.112 21 0.317	0.292 21 0.098	-0.449 21 0.02	0.57 21 0.004	-0.145 21 0.268	0.113 21 0.315	-0.177 21 0.225	-0.079 21 0.365	-0.426 21 0.026
Sc	0.422 21 0.02	0.112 21 0.317	0.218 21 0.172	0.248 21 0.139	-0.314 20 0.087	0.418 21 0.029	-0.318 21 0.078	0.425 21 0.026	0.078 21 0.366	-0.012 21 0.456	0.831 21 0	0.523 21 0.007	0.339 21 0.064	0.077 21 0.368
Se	-0.012 21 0.456	-0.042 21 0.417	0.839 21 0	0.825 21 0	-0.397 20 0.04	-0.048 21 0.409	-0.198 21 0.198	0.075 21 0.37	0.523 21 0.007	-0.134 21 0.285	0.771 21 0	0.322 21 0.075	0.345 21 0.061	-0.149 21 0.262
SiO_2	1	0.158 21 0.25	-0.211 30 0.132	-0.248 21 0.139	-0.003 20 0.469	0.117 21 0.31	-0.685 30 0	0.487 21 0.012	-0.416 21 0.029	0.149 21 0.262	0.205 21 0.188	-0.116 21 0.312	0.182 21 0.218	0.313 21 0.082
Sm	~~0.158~~ ~~21~~ ~~0.25~~	1	-0.195 21 0.201	-0.149 21 0.262	0.048 20 0.41	0.271 21 0.116	-0.267 21 0.12	0.317 21 0.079	-0.395 21 0.037	-0.006 21 0.463	-0.034 21 0.428	0.54 21 0.005	0.548 21 0.005	0.553 21 0.004
SO_4	~~-0.211~~ ~~30~~ ~~0.132~~	~~-0.195~~ ~~21~~ ~~0.201~~	1	0.953 21 0	-0.266 20 0.128	-0.153 21 0.257	-0.158 30 0.204	-0.357 21 0.054	0.648 21 0.001	0.001 21 0.472	0.519 21 0.007	0.195 21 0.201	0.279 21 0.109	-0.312 21 0.083
Sr	~~-0.248~~ ~~21~~ ~~0.139~~	~~-0.149~~ ~~21~~ ~~0.262~~	~~0.953~~ ~~21~~ ~~0~~	1	-0.322 20 0.082	-0.009 21 0.46	-0.17 21 0.233	-0.243 21 0.145	0.731 21 0	0.174 21 0.228	0.54 21 0.005	0.197 21 0.198	0.353 21 0.056	-0.253 21 0.134
T.U.	~~-0.003~~ ~~20~~ ~~0.469~~	~~0.048~~ ~~20~~ ~~0.41~~	~~-0.266~~ ~~20~~ ~~0.128~~	~~-0.322~~ ~~20~~ ~~0.082~~	1	0.192 20 0.211	0.186 20 0.219	-0.268 20 0.126	-0.244 20 0.15	0.023 20 0.444	-0.245 20 0.149	-0.153 20 0.262	-0.138 20 0.283	-0.415 20 0.033
Tb	~~0.117~~ ~~21~~ ~~0.31~~	~~0.271~~ ~~21~~ ~~0.116~~	~~-0.153~~ ~~21~~ ~~0.257~~	~~-0.009~~ ~~21~~ ~~0.46~~	~~0.192~~ ~~20~~ ~~0.211~~	1	0.068 21 0.382	0.257 21 0.13	0.053 21 0.401	0.247 21 0.14	0.36 21 0.053	0.37 21 0.047	0.196 21 0.199	-0.064 21 0.387
temp.	~~-0.685~~ ~~30~~ ~~0~~	~~-0.267~~ ~~21~~ ~~0.12~~	~~-0.158~~ ~~30~~ ~~0.204~~	~~-0.17~~ ~~21~~ ~~0.233~~	~~0.186~~ ~~20~~ ~~0.219~~	~~0.068~~ ~~21~~ ~~0.382~~	1	-0.054 21 0.401	0.133 21 0.287	-0.183 21 0.216	-0.203 21 0.19	-0.096 21 0.34	-0.33 21 0.071	-0.45 21 0.02
Th	~~0.487~~ ~~21~~ ~~0.012~~	~~0.317~~ ~~21~~ ~~0.079~~	~~-0.357~~ ~~21~~ ~~0.054~~	~~-0.243~~ ~~21~~ ~~0.145~~	~~-0.268~~ ~~20~~ ~~0.126~~	~~0.257~~ ~~21~~ ~~0.13~~	~~-0.054~~ ~~21~~ ~~0.401~~	1	-0.206 21 0	0.17 21 0.234	0.256 21 0	0.077 21 0.368	0.295 21 0.096	0.343 21 0.063
Tl	~~-0.416~~ ~~21~~ ~~0.029~~	~~-0.395~~ ~~21~~ ~~0.037~~	~~0.648~~ ~~21~~ ~~0.001~~	~~0.731~~ ~~21~~ ~~0~~	~~-0.244~~ ~~20~~ ~~0.15~~	~~0.053~~ ~~21~~ ~~0.401~~	~~0.133~~ ~~21~~ ~~0.287~~	~~-0.206~~ ~~21~~ ~~0~~	1	0.13 21 0.29	0.371 21 0	-0.027 21 0.437	0.062 21 0.389	-0.499 21 0.01
Tm	~~0.149~~ ~~21~~ ~~0.262~~	~~-0.006~~ ~~21~~ ~~0.463~~	~~0.001~~ ~~21~~ ~~0.472~~	~~0.174~~ ~~21~~ ~~0.228~~	~~0.023~~ ~~20~~ ~~0.444~~	~~0.247~~ ~~21~~ ~~0.14~~	~~-0.183~~ ~~21~~ ~~0.216~~	~~0.17~~ ~~21~~ ~~0.234~~	~~0.13~~ ~~21~~ ~~0.29~~	1	-0.038 21 0.423	0.006 21 0.463	0.416 21 0.029	0.053 21 0.401
U	~~0.205~~ ~~21~~ ~~0.188~~	~~-0.034~~ ~~21~~ ~~0.428~~	~~0.519~~ ~~21~~ ~~0.007~~	~~0.54~~ ~~21~~ ~~0.005~~	~~-0.245~~ ~~20~~ ~~0.149~~	~~0.36~~ ~~21~~ ~~0.053~~	~~-0.203~~ ~~21~~ ~~0.19~~	~~0.256~~ ~~21~~ ~~0~~	~~0.371~~ ~~21~~ ~~0~~	~~-0.038~~ ~~21~~ ~~0.423~~	1	0.349 21 0.058	0.2 21 0.194	-0.188 21 0.209
Y	~~-0.116~~ ~~21~~ ~~0.312~~	~~0.54~~ ~~21~~ ~~0.005~~	~~0.195~~ ~~21~~ ~~0.201~~	~~0.197~~ ~~21~~ ~~0.198~~	~~-0.153~~ ~~20~~ ~~0.262~~	~~0.37~~ ~~21~~ ~~0.047~~	~~-0.096~~ ~~21~~ ~~0.34~~	~~0.077~~ ~~21~~ ~~0.368~~	~~-0.027~~ ~~21~~ ~~0.437~~	~~0.006~~ ~~21~~ ~~0.463~~	~~0.349~~ ~~21~~ ~~0.058~~	1	0.488 21 0.012	0.194 21 0.203
Yb	~~0.182~~ ~~21~~ ~~0.218~~	~~0.548~~ ~~21~~ ~~0.005~~	~~0.279~~ ~~21~~ ~~0.109~~	~~0.353~~ ~~21~~ ~~0.056~~	~~-0.138~~ ~~20~~ ~~0.283~~	~~0.196~~ ~~21~~ ~~0.199~~	~~-0.33~~ ~~21~~ ~~0.071~~	~~0.295~~ ~~21~~ ~~0.096~~	~~0.062~~ ~~21~~ ~~0.389~~	~~0.416~~ ~~21~~ ~~0.029~~	~~0.2~~ ~~21~~ ~~0.194~~	~~0.488~~ ~~21~~ ~~0.012~~	1	0.232 21 0.156
Zn	~~0.313~~ ~~21~~ ~~0.082~~	~~0.553~~ ~~21~~ ~~0.004~~	~~-0.312~~ ~~21~~ ~~0.083~~	~~-0.253~~ ~~21~~ ~~0.134~~	~~-0.415~~ ~~20~~ ~~0.033~~	~~-0.064~~ ~~21~~ ~~0.387~~	~~-0.45~~ ~~21~~ ~~0.02~~	~~0.343~~ ~~21~~ ~~0.063~~	~~-0.499~~ ~~21~~ ~~0.01~~	~~0.053~~ ~~21~~ ~~0.401~~	~~-0.188~~ ~~21~~ ~~0.209~~	~~0.194~~ ~~21~~ ~~0.203~~	~~0.232~~ ~~21~~ ~~0.156~~	1

App.No.32.: Saturation indices (samples June/July 1999)

(calculated with the program PhreeqC2, elements considered: temperature, pH, pe, NO_2, P, HCO_3, K, Na, Mg, Ca, Cl, SO_4, Si, F, NO_3 and from ICP: Li, B, Al, Mn, Fe, Ni, Cu, Zn, Cd, As, Se, Sr, Ba, Pb, U as far as they were determined)

saturation indices **cluster group (1)**		**P3**	**P9**	**P16**	**P17**	**PSD**	**Encinito 2**	**Huerta los Pinos**	**mean**
Alunite	$KAl_3(SO_4)_2(OH)_6$	0.55	-0.7	-0.34	-2.65	-1.35			-0.90
Anhydrite	$CaSO_4$	-1.72	-2.68	-1.97	-2.93	-2.58	-1.41	-1.23	-2.07
Aragonite	$CaCO_3$	-0.21	-0.3	-0.29	-0.39	-0.23	-0.1	-0.04	-0.22
$Ba_3(AsO_4)_2$	$Ba_3(AsO_4)_2$	7.69	8.18	7.28	7.79	8.12			7.81
Barite	$BaSO_4$	0.43	-0.17	0.04	-0.55	-0.15			-0.08
Basaluminite	$Al_4(OH)_{10}SO_4$	1.28	0.78	-0.27	-1.54	-0.08			0.03
Boehmite	AlOOH	1.84	1.86	1.63	1.39	1.71			1.69
Calcite	$CaCO_3$	-0.07	-0.16	-0.15	-0.25	-0.09	0.04	0.1	-0.08
Chalcedony	SiO_2	-0.31	0.01	-0.26	-0.03	-0.02	-0.26	-0.05	-0.13
Clpyromorphite	$Pb_5(PO_4)_3Cl$	0.26	2.55	1.79	0.69	1.41			1.34
Cristobalite	SiO_2	-0.27	0.04	-0.23	0	0.01	-0.23	-0.01	-0.10
CupricFerrite	$CuFe_2O_4$	13.68	14.17	14.88	13.9	15.03			14.33
CuprousFerrite	$CuFeO_2$	10.84	10.25	12.85	11.55	13.14			11.73
Diaspore	AlOOH	3.54	3.57	3.31	3.08	3.41			3.38
Dolomite	$CaMg(CO_3)_2$	-0.52	-0.87	-0.46	-0.98	-0.68	-0.27	-0.24	-0.57
Dolomite(d)	$CaMg(CO_3)_2$	-1.07	-1.43	-1	-1.53	-1.22	-0.81	-0.79	-1.12
FCO_3Apatite	$Ca_{9.316}Na_{0.36}Mg_{0.144}(PO_4)_{4.8}(CO_3)_{1.2}F_{2.48}$	12	14	11.87	10.52	12.04	13.94	14.8	12.74
$Fe(OH)_{2.7}Cl_{0.3}$	$Fe(OH)_{2.7}Cl_{0.3}$	6.44	6.67	6.88	6.54	7			6.71
$Fe(OH)_3$(a)	$Fe(OH)_3$	1.71	1.95	2.26	1.89	2.3			2.02
$Fe_3(OH)_8$	$Fe_3(OH)_8$	-1.07	-1.31	2.05	0.13	2.21			0.40
Fluorapatite	$Ca_5(PO_4)_3F$	1.04	2.11	1.02	0.3	1.1	1.88	2.38	1.40
Fluorite	CaF_2	-1.73	-1.72	-1.31	-2.22	-2.26	-1.01	-1.48	-1.68
Gibbsite	$Al(OH)_3$	2.3	2.34	2.06	1.85	2.17			2.14
Goethite	FeOOH	7.65	7.82	8.27	7.82	8.22			7.96
Gypsum	$CaSO_4{:}2H_2O$	-1.5	-2.45	-1.76	-2.71	-2.36	-1.19	-1.02	-1.86
Halite	NaCl	-8.57	-8.05	-8.82	-8.6	-8.21	-8.39	-8.04	-8.38
Halloysite	$Al_2Si_2O_5(OH)_4$	0.62	1.31	0.25	0.27	0.92			0.67
Hematite	Fe_2O_3	17.32	17.65	18.57	17.66	18.46			17.93
Illite	$K_{0.6}Mg_{0.25}Al_{2.3}Si_{3.5}O_{10}(OH)_2$	2.93	4.43	2.66	2.94	3.81			3.35
Kaolinite	$Al_2Si_2O_5(OH)_4$	5.67	6.37	5.27	5.32	5.98			5.72
Maghemite	Fe_2O_3	6.82	7.29	7.92	7.19	8			7.44
Magnetite	Fe_3O_4	15.58	15.13	18.96	16.75	18.81			17.05
Montmorillonite-Aberdeen	$(HNaK)_{0.14}Mg_{0.45}Fe_{0.33}Al_{1.47}Si_{3.82}O_{10}(OH)_2$	5.01	6.27	5.3	5.39	6.14			5.62
Montmorillonite-BelleFourche	$(HNaK)_{0.09}Mg_{0.29}Fe_{0.24}Al_{1.57}Si_{3.93}O_{10}(OH)_2$	5.95	7.18	6.18	6.32	7.02			6.53
Montmorillonite-Ca	$Ca_{0.165}Al_{2.33}Si_{3.67}O_{10}(OH)_2$	4.19	5.43	3.8	4.12	4.94			4.50
Plumbogummite	$PbAl_3(PO_4)_2(OH)_5{:}H_2O$	3.24	4.46	2.73	2.16	3.17			3.15
Quartz	SiO_2	0.12	0.44	0.16	0.4	0.4	0.16	0.38	0.29
Silicagel	SiO_2	-0.84	-0.53	-0.79	-0.56	-0.55	-0.8	-0.58	-0.66
SiO_2(a)	SiO_2	-1.14	-0.83	-1.09	-0.87	-0.86	-1.1	-0.89	-0.97
Strengite	$FePO_4{:}2H_2O$	0.25	0.73	0.94	0.5	0.84			0.65
$ZnSiO_3$	$ZnSiO_3$	0.94	1.72	1.27	0.97	1.35			1.25

saturation indices **cluster group (2)**		**P12**	**Chilera**	**El Peloteado**	**Encinito1**	**Dona Matilde**	**Las Guayabas**	**mean**
Alunite	$KAl_3(SO_4)_2(OH)_6$	4.82	2.38	4.21	4.65			4.02
Anhydrite	$CaSO_4$	-0.67	-0.9	-0.87	-0.68	-0.63	-0.66	-0.74
Aragonite	$CaCO_3$	-0.15	-0.15	-0.14	-0.15	-0.08	-0.11	-0.13
$Ba_3(AsO_4)_2$	$Ba_3(AsO_4)_2$	5.07	5.33	5.79	5.3			5.37
Barite	$BaSO_4$	0.52	0.22	0.26	0.48			0.37
Basaluminite	$Al_4(OH)_{10}SO_4$	4.47	2.19	4.17	4.18			3.75
Boehmite	AlOOH	2.48	1.77	2.41	2.4			2.27
Calcite	$CaCO_3$	-0.01	-0.01	0	-0.01	0.06	0.03	0.01
Chalcedony	SiO_2	-0.44	-0.11	-0.06	-0.37	-0.17	-0.42	-0.26
Clpyromorphite	$Pb_5(PO_4)_3Cl$	1.63	0.93	0.31	-1.76			0.28
Cristobalite	SiO_2	-0.41	-0.08	-0.03	-0.34	-0.13	-0.4	-0.23
CupricFerrite	$CuFe_2O_4$	15.05	14	13.71	13.33			14.02
CuprousFerrite	$CuFeO_2$	11.61	12.2	12.52	11.94			12.07
Diaspore	AlOOH	4.15	3.47	4.09	4.07			3.95
Dolomite	$CaMg(CO_3)_2$	-0.33	-0.47	-0.58	-0.37	-0.29	-0.27	-0.39
Dolomite(d)	$CaMg(CO_3)_2$	-0.87	-1.02	-1.12	-0.9	-0.84	-0.81	-0.93
FCO_3Apatite	$Ca_{9.316}Na_{0.36}Mg_{0.144}(PO_4)_{4.8}(CO_3)_{1.2}F_{2.48}$	14.82	12.95	12.08	10.02	13.33	12.72	12.65
$Fe(OH)_{2.7}Cl_{0.3}$	$Fe(OH)_{2.7}Cl_{0.3}$	6.88	6.72	6.55	6.35			6.63
$Fe(OH)_3$(a)	$Fe(OH)_3$	2.12	1.88	1.64	1.53			1.79
$Fe_3(OH)_8$	$Fe_3(OH)_8$	0.12	0.55	0.38	-0.22			0.21
Fluorapatite	$Ca_5(PO_4)_3F$	2.68	1.15	0.85	-0.33	1.43	1.23	1.17
Fluorite	CaF_2	-0.72	-0.86	-0.82	-0.75	-1.41	-0.51	-0.85
Gibbsite	$Al(OH)_3$	2.9	2.24	2.85	2.83			2.71
Goethite	FeOOH	8.15	7.77	7.63	7.55			7.78
Gypsum	$CaSO_4:2H_2O$	-0.47	-0.68	-0.66	-0.48	-0.41	-0.46	-0.53
Halite	NaCl	-8.6	-7.79	-7.74	-8.28	-7.81	-8.66	-8.15
Halloysite	$Al_2Si_2O_5(OH)_4$	1.58	0.87	2.23	1.57			1.56
Hematite	Fe_2O_3	18.33	17.54	17.27	17.13			17.57
Illite	$K_{0.6}Mg_{0.25}Al_{2.3}Si_{3.5}O_{10}(OH)_2$	3.73	3.55	5.05	3.81			4.04
Kaolinite	$Al_2Si_2O_5(OH)_4$	6.6	5.94	7.26	6.59			6.60
Maghemite	Fe_2O_3	7.65	7.15	6.68	6.45			6.98
Magnetite	Fe_3O_4	17.09	17.04	17.18	16.74			17.01
Montmorillonite-Aberdeen	$(HNaK)_{0.14}Mg_{0.45}Fe_{0.33}Al_{1.47}Si_{3.82}O_{10}(OH)_2$	5.65	5.6	6.77	5.6			5.91
Montmorillonite-BelleFourche	$(HNaK)_{0.09}Mg_{0.29}Fe_{0.24}Al_{1.57}Si_{3.93}O_{10}(OH)_2$	6.68	6.52	7.85	6.68			6.93
Montmorillonite-Ca	$Ca_{0.165}Al_{2.33}Si_{3.67}O_{10}(OH)_2$	5.09	4.74	6.37	5.16			5.34
Plumbogummite	$PbAl_3(PO_4)_2(OH)_5:H_2O$	6.06	3.29	4.55	3.76			4.42
Quartz	SiO_2	-0.02	0.31	0.36	0.05	0.26	-0.01	0.16
Silicagel	SiO_2	-0.97	-0.65	-0.59	-0.9	-0.71	-0.96	-0.80
SiO_2(a)	SiO_2	-1.26	-0.95	-0.89	-1.19	-1.01	-1.25	-1.09
Strengite	$FePO_4:2H_2O$	1.53	0.37	0.18	-0.04			0.51
$ZnSiO_3$	$ZnSiO_3$	0.66	0.59	0.44	-0.19			0.38

saturation indices **cluster group (3)**		**Anteojitos**	**Ojo de Agua**	**Media Luna A**	**Media Luna B/C**	**Media Luna D**	**Media Luna E**	**Media Luna F**	**Media Luna cave**	**mean**
Alunite	$KAl_3(SO_4)_2(OH)_6$	0.79	2.44	---	1.05	---	---	0.43	1.68	1.28
Anhydrite	$CaSO_4$	-0.52	-0.64	-0.58	-0.57	-0.58	-0.56	-0.53	-0.57	-0.57
Aragonite	$CaCO_3$	0.32	0.01	0.3	0.21	0.3	0.31	0.27	0.19	0.24
$Ba_3(AsO_4)_2$	$Ba_3(AsO_4)_2$	4.52	4.33	---	4.14	---	---	4.14	4.39	4.30
Barite	$BaSO_4$	0.14	0.17	---	0.04	---	---	0.02	0.13	0.10
Basaluminite	$Al_4(OH)_{10}SO_4$	-0.56	1.35	---	-0.11	---	---	-1.61	0.87	-0.01
Boehmite	$AlOOH$	1.48	1.78	---	1.47	---	---	1.36	1.65	1.55
Calcite	$CaCO_3$	0.46	0.15	0.44	0.36	0.44	0.45	0.41	0.33	0.38
Chalcedony	SiO_2	-0.48	-0.43	-0.46	-0.46	-0.46	-0.45	-0.5	-0.44	-0.46
Clpyromorphite	$Pb_5(PO_4)_3Cl$	5.3	-0.55	---	---	---	---	---	---	2.38
Cristobalite	SiO_2	-0.46	-0.4	-0.43	-0.43	-0.43	-0.43	-0.47	-0.41	-0.43
CupricFerrite	$CuFe_2O_4$	13.73	12.2	---	12.99	---	---	13.29	13.09	13.06
CuprousFerrite	$CuFeO_2$	13.31	12.76	---	13.02	---	---	13.08	13.13	13.06
Diaspore	$AlOOH$	3.14	3.45	---	3.14	---	---	3	3.33	3.21
Dolomite	$CaMg(CO_3)_2$	0.54	-0.06	0.53	0.34	0.56	0.55	0.49	0.31	0.41
Dolomite(d)	$CaMg(CO_3)_2$	0.01	-0.59	-0.01	-0.19	0.02	0.02	-0.03	-0.23	-0.13
$FCO_3Apatite$	$Ca_{9.316}Na_{0.36}Mg_{0.144}(PO_4)_{4.8}(CO_3)_{1.2}F_{2.48}$	14.81	8.99	---	---	---	---	---	---	11.90
$Fe(OH)_{2.7}Cl_{0.3}$	$Fe(OH)_{2.7}Cl_{0.3}$	6.22	5.62	---	5.96	---	---	5.93	6.03	5.95
$Fe(OH)_3(a)$	$Fe(OH)_3$	1.51	0.87	---	1.24	---	---	1.18	1.3	1.22
$Fe_3(OH)_8$	$Fe_3(OH)_8$	0.75	-0.86	---	0.08	---	---	-0.21	0.26	0.00
Fluorapatite	$Ca_5(PO_4)_3F$	2.36	-1.1	---	---	---	---	---	---	0.63
Fluorite	CaF_2	-0.43	-0.47	-0.42	-0.42	-0.43	-0.43	-0.47	-0.43	-0.44
Gibbsite	$Al(OH)_3$	1.88	2.2	---	1.89	---	---	1.73	2.08	1.96
Goethite	$FeOOH$	7.58	6.92	---	7.27	---	---	7.13	7.22	7.22
Gypsum	$CaSO_4{:}2H_2O$	-0.33	-0.44	-0.38	-0.36	-0.37	-0.36	-0.35	-0.37	-0.37
Halite	$NaCl$	-8.34	-8.53	-8.44	-8.44	-8.45	-8.37	-8.32	-8.37	-8.41
Halloysite	$Al_2Si_2O_5(OH)_4$	-0.53	0.19	---	-0.49	---	---	-0.84	-0.07	-0.35
Hematite	Fe_2O_3	17.19	15.86	---	16.58	---	---	16.74	16.61	16.60
Illite	$K_{0.6}Mg_{0.25}Al_{2.3}Si_{3.5}O_{10}(OH)_2$	1.68	2.26	---	1.64	---	---	1.22	2.17	1.79
Kaolinite	$Al_2Si_2O_5(OH)_4$	4.47	5.2	---	4.53	---	---	4.13	4.96	4.66
Maghemite	Fe_2O_3	6.41	5.14	---	5.88	---	---	5.75	6	5.84
Magnetite	Fe_3O_4	17.87	16.16	---	17.05	---	---	17.24	17.11	17.09
Montmorillonite-Aberdeen	$(HNaK)_{0.14}Mg_{0.45}Fe_{0.33}Al_{1.47}Si_{3.82}O_{10}(OH)_2$	4.37	4.39	---	4.13	---	---	4.18	4.42	4.30
Montmorillonite-BelleFourche	$(HNaK)_{0.09}Mg_{0.29}Fe_{0.24}Al_{1.57}Si_{3.93}O_{10}(OH)_2$	5.2	5.42		5.01			5.07	5.31	5.20
Montmorillonite-Ca	$Ca_{0.165}Al_{2.33}Si_{3.67}O_{10}(OH)_2$	7.28	3.51		2.74			2.28	3.26	3.81
Plumbogummite	$PbAl_3(PO_4)_2(OH)_5{:}H_2O$	1.62	1.15							1.39
Quartz	SiO_2	-0.07	-0.02	-0.04	-0.04	-0.04	-0.04	-0.09	-0.02	-0.05
Silicagel	SiO_2	-1.01	-0.96	-0.99	-0.99	-0.99	-0.98	-1.02	-0.97	-0.99
$SiO_2(a)$	SiO_2	-1.3	-1.26	-1.28	-1.29	-1.28	-1.28	-1.31	-1.27	-1.28
Strengite	$FePO_4{:}2H_2O$	-0.47	-1.36							-0.92
$ZnSiO_3$	$ZnSiO_3$	0.23	-0.29		-0.02			0.1	0.19	0.04

saturation indices **cluster group (4)**		**Cabana**	**Pastora**	**Chamizal**	**Vergel1**	**Vergel2**	**Santo Domingo**	**San Isidro**	**Rancho#13**	**La Gloria**	**mean**
Alunite	$KAl_3(SO_4)_2(OH)_6$	3.08	2.71		3.52	5.82	5.3	2.61	4.74		3.97
Anhydrite	$CaSO_4$	-0.22	-0.25	-0.41	-0.27	-0.31	-0.31	-0.24	-0.22	-0.33	-0.28
Aragonite	$CaCO_3$	0.22	0.11	-0.03	-0.05	-0.08	-0.06	0.11	0.14	0.02	0.04
$Ba_3(AsO_4)_2$	$Ba_3(AsO_4)_2$	4.23	3.45		4.01	4.51	4.57	4.36	5.24		4.34
Barite	$BaSO_4$	0.16	0.01		0.2	0.35	0.28	0.23	0.23		0.21
Basaluminite	$Al_4(OH)_{10}SO_4$	2.43	1.91		2.52	5.42	5.05	1.83	3.99		3.31
Boehmite	AlOOH	1.82	1.67		1.76	2.56	2.4	1.6	2.29		2.01
Calcite	$CaCO_3$	0.36	0.26	0.12	0.09	0.06	0.08	0.26	0.29	0.16	0.19
Chalcedony	SiO_2	-0.19	-0.17	-0.22	-0.19	-0.2	-0.33	-0.17	-0.13	-0.11	-0.19
Clpyromorphite	$Pb_5(PO_4)_3Cl$	-1.24	2.93		-0.88	-1.22	0.01	-0.37	1.54		0.11
Cristobalite	SiO_2	-0.16	-0.13	-0.18	-0.15	-0.17	-0.3	-0.13	-0.09	-0.07	-0.15
CupricFerrite	$CuFe_2O_4$	11.93	14.66		13.78	14.03	15.09	15.75	13.67		14.13
CuprousFerrite	$CuFeO_2$	13.85	12.07		11.7	10.48	13.16	12.61	10.81		12.10
Diaspore	AlOOH	3.53	3.38		3.46	4.26	4.11	3.31	3.97		3.72
Dolomite	$CaMg(CO_3)_2$	0.73	0.36	-0.05	-0.01	0.15	-0.13	0.11	0.28	0.15	0.18
Dolomite(d)	$CaMg(CO_3)_2$	0.18	-0.19	-0.6	-0.56	-0.39	-0.68	-0.44	-0.26	-0.4	-0.37
FCO_3Apatite	$Ca_{9.316}Na_{0.36}Mg_{0.144}(PO_4)_{4.8}(CO_3)_{1.2}F_{2.48}$	16.1	17.76	17.05	15.22	13.33	14.62	15.82	17.93	15.95	15.98
$Fe(OH)_{2.7}Cl_{0.3}$	$Fe(OH)_{2.7}Cl_{0.3}$	5.56	6.88		6.73	6.79	7.07	7.63	6.74		6.77
$Fe(OH)_3$(a)	$Fe(OH)_3$	0.81	2.16		1.83	1.95	2.26	2.75	1.73		1.93
$Fe_3(OH)_8$	$Fe_3(OH)_8$	-0.02	0.88		0.07	-0.83	1.95	2.65	-0.98		0.53
Fluorapatite	$Ca_5(PO_4)_3F$	2.55	3.68	3.36	2.12	1.23	1.81	2.4	3.88	2.71	2.64
Fluorite	CaF_2	-0.24	-0.13	-0.04	-0.2	-0.34	-0.04	-0.11	-0.04	-0.42	-0.17
Gibbsite	$Al(OH)_3$	2.3	2.15		2.23	3.02	2.88	2.08	2.73		2.48
Goethite	FeOOH	6.69	8.04		7.71	7.89	8.14	8.61	7.69		7.82
Gypsum	$CaSO_4{:}2H_2O$	0	-0.02	-0.19	-0.05	-0.1	-0.08	-0.02	-0.01	-0.11	-0.06
Halite	NaCl	-7.47	-7.78	-7.21	-6.76	-7.55	-7.5	-7.13	-6.66	-7.16	-7.25
Halloysite	$Al_2Si_2O_5(OH)_4$	0.83	0.58		0.71	2.27	1.71	0.44	1.86		1.20
Hematite	Fe_2O_3	15.39	18.09		17.44	17.8	18.3	19.23	17.4		17.66
Illite	$K_{0.6}Mg_{0.25}Al_{2.3}Si_{3.5}O_{10}(OH)_2$	4.07	3.7		3.75	5.36	4.69	3.42	5.11		4.30
Kaolinite	$Al_2Si_2O_5(OH)_4$	5.9	5.64		5.78	7.31	6.78	5.51	6.9		6.26
Maghemite	Fe_2O_3	5.01	7.72		7.06	7.29	7.93	8.89	6.86		7.25
Magnetite	Fe_3O_4	16.44	17.33		16.53	15.84	18.4	19.03	15.74		17.04
Montmorillonite-Aberdeen	$(HNaK)_{0.14}Mg_{0.45}Fe_{0.33}Al_{1.47}Si_{3.82}O_{10}(OH)_2$	5.72	5.87		5.73	6.94	6.16	5.78	6.86		6.15
Montmorillonite-BelleFourche	$(HNaK)_{0.09}Mg_{0.29}Fe_{0.24}Al_{1.57}Si_{3.93}O_{10}(OH)_2$	6.49	6.56		6.49	7.81	6.96	6.45	7.71		6.92
Montmorillonite-Ca	$Ca_{0.165}Al_{2.33}Si_{3.67}O_{10}(OH)_2$	4.71	4.43		4.51	6.26	5.48	4.26	5.94		5.08
Plumbogummite	$PbAl_3(PO_4)_2(OH)_5{:}H_2O$	2.11	3.24		2.53	4.58	4.46	1.92	4.61		3.35
Quartz	SiO_2	0.24	0.26	0.21	0.24	0.22	0.1	0.27	0.3	0.32	0.24
Silicagel	SiO_2	-0.73	-0.7	-0.75	-0.72	-0.73	-0.87	-0.7	-0.66	-0.64	-0.72
SiO_2(a)	SiO_2	-1.03	-1.01	-1.06	-1.03	-1.04	-1.17	-1.01	-0.96	-0.95	-1.03
Strengite	$FePO_4{:}2H_2O$	-1.42	0.45		0.06	0.19	0.31	0.71	0.34		0.09
$ZnSiO_3$	$ZnSiO_3$	1.1	0.37		-0.15	0.4	0.58	0.73	0.19		0.46

App.No.33.: SiO_2 geothermometer - calculated temperature

(calculation of formation temperature according to FOURNIER (1981) equations for chalcedony (if $SI_{chalcedony}$ > -0.06) or quartz (if $SI_{chalcedony}$ < -0.06 and quartz is the only predominant SiO_2 modification)

June/July sampling	SiO_2(mg/L)	SI_{quartz}	$SI_{chalcedony}$	calculated temperature [°C]	**October sampling**	SiO_2(mg/L)	SI_{quartz}	$SI_{chalcedony}$	calculated temperature [°C]
P3	27.37	-0.31	0.12	75.66	P3	32.62	-0.31	0.12	82.89
P9	53.93	0.01	0.44	75.71	P9	54.9	0.01	0.44	76.63
P16	32.16	-0.26	0.16	82.30	P16	19.94	-0.26	0.16	63.33
P17	51.55	-0.03	0.4	73.42	P17	25.2	-0.03	0.4	40.66
PSD	52.25	-0.02	0.4	74.10	PSD	54.3	-0.02	0.4	76.06
El Encinito II	29.68	-0.26	0.16	78.96	PSM	48.12			69.97
Huerta los Pinos	47.75	-0.05	0.38	69.59	El Encinito II	30.81	-0.26	0.16	80.51
P12	21.59	-0.44	-0.02	66.34	P12	20.4	-0.44	-0.02	64.19
Chilera	40.97	-0.11	0.31	92.74	Chilera	41.35	-0.11	0.31	93.16
El Peloteado	49.97	-0.06	0.36	71.85	El Peloteado	57.27	-0.06	0.36	78.82
El Encinito I	25.34	-0.37	0.05	72.58	El Encinito I	26.16	-0.37	0.05	73.85
Doña Matilde	35.02	-0.17	0.26	85.90	Doña Matilde	36.96	-0.17	0.26	88.23
Las Guayabas	21.9	-0.42	-0.01	66.89	Las Guayabas	21.87	-0.42	-0.01	66.84
Media Luna (Crater A)	20.74	-0.46	-0.04	64.81	Media Luna	22.33	-0.46	-0.04	67.64
Media Luna (Crater B/C)	20.49	-0.46	-0.04	64.36	Anteojitos	21.52	-0.48	-0.07	66.22
Media Luna (Crater D)	20.68	-0.46	-0.04	64.70	Ojo de Agua de Solano	23.34	-0.43	-0.02	69.35
Media Luna (Crater E)	20.85	-0.45	-0.04	65.01	Charco Azul	22.75			68.36
Media Luna (Crater F)	20.95	-0.5	-0.09	65.20	Chamizal	34.56	-0.22	0.21	85.34
Media Luna (Cave)	20.96	-0.44	-0.02	65.21	Pastora	37.08	-0.17	0.26	88.37
Anteojitos	20.16	-0.48	-0.07	63.74	Santo Domingo	37.18	-0.33	0.1	88.48
Ojo de Agua de Solano	22.18	-0.43	-0.02	67.38	Vergel I	34.82	-0.19	0.24	85.66
Pastora	35.8	-0.17	0.26	86.85	Vergel II	37.04	-0.2	0.22	88.32
Chamizal	32.1	-0.22	0.21	82.22	Rancho #13	44.75	-0.13	0.3	96.71
San Isidro	35.35	-0.17	0.27	86.31					
Santo Domingo	24.35	-0.33	0.1	71.01					
Vergel I	34.1	-0.19	0.24	84.77					
Vergel II	34.5	-0.2	0.22	85.27					
Rancho #13	41.55	-0.13	0.3	93.37					
La Gloria	41.15	-0.19	0.24	92.94					
La Cabana	33.7	-0.19	0.24	84.27					

App.No.34.: Input files for PhreeqC invers modeling

(solution 1 = average low mineralized rain water (GRANAT 1976), solution 2 = analyzed groundwater from P9 (1), Chilera (2), Media Luna (3) and Pastora (4) as representatives for each cluster group)

(1) groundwater sample P9

```
TITLE  Inverse modeling P9
SOLUTION_SPREAD
Number    pH     Si    Ca     Mg     Na    K      Alkalinity   S(6)   Cl
1         4.6    0     0.025  0.011  0.05  0.006  0.021        0.035  0.055
2         7.17   0.9   3.13   0.65   1.24  0.16   4            0.29   0.32

INVERSE_MODELING 1
        -solutions 1 2
        -uncertainty 0.30
        -range
        -phases
                CO2(g)
                gypsum
                Calcite
                Dolomite
                CaX2
                NaX
                KX
                Chalcedony
                Quartz
                Kaolinite       precip
                Albite          dissolve
                Halite          dissolve

EXCHANGE_MASTER_SPECIES
        X       X-
EXCHANGE_SPECIES
        X- = X-
        log_k           0.0

        Na+ + X- = NaX
        log_k   0.0
        -gamma  4.0     0.075

        K+ + X- = KX
        log_k   0.7
        -gamma  3.5     0.015
        delta_h  -4.3   # Jardine & Sparks, 1984

        Ca+2 + 2X- = CaX2
        log_k   0.8
        -gamma  5.0     0.165
        delta_h  7.2    # Van Bladel & Gheyl, 1980

END
```

(2) groundwater sample Chilera

```
TITLE  Inverse modeling Chilera
SOLUTION_SPREAD
Number   pH    Si    Ca     Mg     Na    K      Alkalinity  S(6)   Cl
1        4.6   0     0.025  0.011  0.05  0.006  0.021       0.035  0.055
2        6.93  0.68  10.92  2.93   1.65  0.12   4.02        10.7   0.51

INVERSE_MODELING 1
    -solutions 1 2
    -uncertainty 0.2
   -balance
     Mg 0.4
    -range
    -phases
            Gypsum
            CO2(g)
            CaX2
            NaX
            KX
            Quartz
            Biotite        dissolve
            Kaolinite      precip
            Albite         dissolve
            Halite         dissolve


PHASES

Biotite
    KMg3AlSi3O10(OH)2 + 6H+ + 4H2O = K+ + 3Mg+2 + Al(OH)4- + 3H4SiO4
    log_k  0.0


EXCHANGE_MASTER_SPECIES
    X     X-
EXCHANGE_SPECIES
    X- = X-
    log_k       0.0

    Na+ + X- = NaX
    log_k   0.0
    -gamma  4.0    0.075

    K+ + X- = KX
    log_k   0.7
    -gamma  3.5    0.015
    delta_h  -4.3   # Jardine & Sparks, 1984

    Ca+2 + 2X- = CaX2
    log_k   0.8
    -gamma  5.0    0.165
    delta_h  7.2    # Van Bladel & Gheyl, 1980


END
```

(3) groundwater sample Media Luna

```
TITLE  Inverse modeling Media Luna
SOLUTION_SPREAD
Number   pH    Si     Ca     Mg     Na     K      Alkalinity   S(6)   Cl
1        4.6   0      0.025  0.011  0.05   0.006   0.021       0.035  0.055
2        7.1   0.34   17.5   5.4    0.8    0.09    5           19     0.25

INVERSE_MODELING 1
       -solutions 1 2
       -uncertainty 0.05
       -balance
        Alkalinity 0.3
       -range
       -phases
              Gypsum
              CO2(g)
              Calcite
              Dolomite
              CaX2
              NaX
              KX
              Quartz
              Kaolinite        precip
              Albite           dissolve
              Halite           dissolve

EXCHANGE_MASTER_SPECIES
       X      X-
EXCHANGE_SPECIES
       X- = X-
       log_k        0.0

       Na+ + X- = NaX
       log_k   0.0
       -gamma  4.0    0.075

       K+ + X- = KX
       log_k   0.7
       -gamma  3.5    0.015
       delta_h  -4.3   # Jardine & Sparks, 1984

       Ca+2 + 2X- = CaX2
       log_k   0.8
       -gamma  5.0    0.165
       delta_h  7.2   # Van Bladel & Gheyl, 1980


END
```

(4) groundwater sample Pastora

```
TITLE  Inverse modeling Pastora
SOLUTION_SPREAD
Number   pH    Si    Ca     Mg     Na    K      Alkalinity   S(6)   Cl
1        4.6   0     0.025  0.011  0.05  0.006  0.021        0.035  0.055
2        7.14  0.6   27.21  14.86  2.91  0.28   3.20         44.56  0.34

INVERSE_MODELING 1
      -solutions 1 2
      -uncertainty 0.066      0.03
      -range
      -phases
              CO2(g)
              gypsum
              calcite
              dolomite
              CaX2
              NaX
              KX
              Quartz
              Biotite          dissolve
              Kaolinite        precip
              Albite           dissolve
              Halite           dissolve


PHASES

Biotite
      KMg3AlSi3O10(OH)2 + 6H+ + 4H2O = K+ + 3Mg+2 + Al(OH)4- + 3H4SiO4
      log_k  0.0


EXCHANGE_MASTER_SPECIES
      X      X-
EXCHANGE_SPECIES
      X- = X-
      log_k         0.0

      Na+ + X- = NaX
      log_k   0.0
      -gamma  4.0     0.075

      K+ + X- = KX
      log_k   0.7
      -gamma  3.5     0.015
      delta_h  -4.3   # Jardine & Sparks, 1984

      Ca+2 + 2X- = CaX2
      log_k   0.8
      -gamma  5.0     0.165
      delta_h  7.2    # Van Bladel & Gheyl, 1980


END
```

App.No.35.: Results for arsenic concentrations in the Rioverde basin

(a) reported arsenic concentrations for wells in the El Refugio area (HOFMANN 1994 & de la Peña 1994)

name	P3	P9	P12	P16	P17	PSD	Media Luna
As (mg/L)	3.3	1.9	3.9	1.9	0.7	3.3	4.9

(b) determined arsenic concentrations for the whole southern part of the Rioverde basin

name	Latitude	Longitude	As extinction	As concentration [µg/L]
San Francisco de la Puebla	21.694	99.846	0.006	3.587
San Rafaelito	21.709	99.868	0.002	1.235
El Tule	21.725	99.861	0.005	2.999
Agua Dulce	21.733	99.871	0.004	2.411
Paso de los Herreros	21.751	99.999	0.004	2.411
Calabazas-Rio Verde	21.759	99.821	0.012	7.115
San Sebastian	21.77	99.823	0.011	6.527
El Capulin	21.831	100.035	0.012	7.115
Los Anteojitos	21.878	100.005	0.011	6.527
Redencion Nacional	21.894	99.886	0.017	10.055
Rancho de la Guadalupana	21.915	99.942	0.012	7.115
PSD	21.919	100.084	0.011	6.527
Emiliano	21.924	100.05	0.021	12.407
P17	21.924	100.091	0.018	10.643
Santa Rita	21.926	99.848	0.029	17.111
P16	21.929	100.093	0.02	11.819
Rancho San Blas I	21.929	99.836	0.014	8.291
Sanguijuela	21.93	99.85	0.004	2.411
irrigation channel ML	21.932	100.03	0.013	7.703
P3	21.932	100.061	0.027	15.935
P12	21.933	100.071	0.008	4.763
Ildefonso Turrubiales	21.935	99.885	0.021	12.407
PX	21.937	100.073	0.012	7.115
P9	21.941	100.081	0.014	8.291
PSM	21.942	100.103	0.018	10.643
La Mezclita	21.943	100.078	0.016	9.467
PX2	21.943	100.073	0.008	4.763
Rancho San Blas II	21.944	99.835	0.031	18.287
Chilera	21.949	100.06	0.022	12.995
El Peloteado	21.951	100.061	0.038	22.403
El Encinito I	21.953	100.08	0.018	10.643
El Encinito II	21.956	100.085	0.023	13.583
Fault well	21.958	100.077	0.006	3.587
Naranjal	21.958	100.041	0.016	9.467
Ojo de Agua de Solano	21.983	100.084	0.006	3.587
Palomares	22.013	100.104	0.01	5.939
La Noria	22.016	100.119	0.011	6.527
near Palomares	22.018	100.092	0.005	2.999
Potrero	22.03	99.859	0.091	53.567
Las Aguras	22.061	100.068	0.032	18.875
El Otomite	22.067	100.076	0.023	13.583
Rancho 13	22.101	100.085	0.067	39.455
Santa Isabel	22.106	100.062	0.003	1.823
Pieras Negras	22.107	100.044	0.006	3.587
San Isidro	22.121	100.078	0.017	10.055
Santo Domingo	22.124	100.085	0.042	24.755
Vergel I	22.127	100.074	0.013	7.703
Vergel II	22.129	100.076	0.024	14.171
Chamizal	22.131	100.091	0.043	25.343
Pastora	22.135	100.059	0.014	8.291
Benito Juarez	22.165	100.007	0.001	0.647
Progreso	22.229	100.126	0.01	5.939

(c) determined arsenic concentrations for the selected wells and springs

(LCC= transformation extinction-concentration by calibration in low concentration range (0-100µg/L in 20µg/L steps), HCC = transformation extinction-concentration by calibration in high concentration range (0-500µg/L in 100µg/L steps)

El Refugio	**P3**	**P9**	**P12**	**P16**	**P17**	**PSD**	**Chilera**	**El Pelo-teado**	**El Enci-nito I**	**El Enci-nito II**
sampling date	08.06.99	07.06.99	07.06.99	08.06.99	07.06.99	07.06.99	08.06.99	10.06.99	10.06.99	10.06.99
As (total) Ext.	0.027	0.014	0.013	0.02	0.018	0.011	0.027	0.038	0.018	0.023
As (total) [ug/L] HCC	12.447	6.454	5.993	9.22	8.298	5.071	12.447	17.518	8.298	10.603
As(total) [ug/L] LCC	15.935	8.291	7.703	11.819	10.643	6.527	15.935	22.403	10.643	13.583
As (III) Ext. I	0.013	0.013	0.007	0.013	0.011	0.006	0.013	0.02	0.008	0.008
As (III) Ext. II	0.01	0.009	0.008	0.01	0.013	0.006	0.016	0.013	0.007	0.005
As (III) [ug/L] LCC	-4.396	5.170	2.177	1.045	3.139	2.116	-1.164	-7.560	-1.710	-6.674
As (V) [ug/L]	20.331	3.121	5.526	10.774	7.504	4.411	17.099	29.963	12.353	20.257
sampling date	15.06.99	18.06.99	14.06.99	15.06.99	15.06.99	19.06.99	19.06.99	16.06.99	17.06.99	17.06.99
As [ug/L] [laboratory]	8.541	6.587	4.580	6.993	3.806	3.585	8.004	9.973	6.445	8.151
As (III) / As(V) ICP calculated with PhreeqC2 [mol/L]	$1.3*10^{-21}$ / $1.1*10^{-7}$	$8.2*10^{-24}$ / $7-1*10^{-8}$	$3.2*10^{-21}$ / $1.3*10^{-7}$	$1.5*10^{-18}$ / $1.5*10^{-7}$	$2.4*10^{-20}$ / $9.1*10^{-8}$	$7.2*10^{-19}$ / $7.8*10^{-8}$	$7.2*10^{-19}$ / $2.1*10^{-7}$	$1.4*10^{-17}$ / $3.1*10^{-7}$	$4.1*10^{-18}$ / $2.0*10^{-7}$	---

Pastora	**La Caba-na**	**Pastora**	**Chamizal**	**Isidro**	**Domingo**	**Vergel I**	**Vergel II**	**Rancho #13**	**Gloria**	
sampling date	01.07.99	30.06.99	03.07.99	02.07.99	02.07.99	02.07.99	30.06.99	01.07.99	01.07.99	
As (total) Ext. I	0.016	0.012	0.036	0.013	0.043	0.017	0.009	0.066	0.009	
As (total) Ext. II	0.016	0.013	0.035	0.011	0.041	0.017	0.01	0.063	0.011	
As (total) [ug/L] HCC	7.376	5.7625	16.3655	5.532	19.362	7.837	4.3795	29.7345	4.61	
As(total) [ug/L] LCC	9.467	7.409	20.933	7.115	24.755	10.055	5.645	37.985	5.939	
As (III) Ext. I	0.014	0.007	0.026	0.013	0.026	0.016	0.009	0.039	0.009	
As (III) Ext. II	0.015	0.005	0.027	0.011	0.028	0.014	0.009	0.041	0.009	
As(III) [ug/L] LCC	7.387	0.950	5.157	7.803	0.643	7.148	6.514	-2.841	6.125	
As(V) [ug/L]	2.080	6.459	15.776	-0.688	24.112	2.907	-0.869	40.826	-0.186	
As [ug/L] (laboratory)	8.59	9.02	26.54	9.82	23.82	7.84	4.15	42.76	4.61	
difference HCC-lab [ug/L]	-1.21	-3.26	-10.17	-4.29	-4.46	0.00	0.23	-13.02	0.00	
difference LCC-lab [ug/L]	0.879	-1.613	-5.605	-2.704	0.932	2.218	1.495	-4.774	1.333	
As (III) / As(V) ICP calculated with PhreeqC2 [mol/L]	$4.1*10^{-14}$/ $2.4*10^{-7}$	$1.8*10^{-20}$/ $1.7*10^{-7}$	---	$3.3*10^{-20}$/ $2.2*10^{-7}$	$1.7*10^{-18}$/ $2.6*10^{-7}$	$1.0*10^{-19}$/ $2.3*10^{-7}$	$4.8*10^{-22}$/ $2.2*10^{-7}$	$7.6*10^{-21}$/ $6.1*10^{-7}$	---	

Media Luna	**Crater A**	**Crater B/ C**	**Crater D**	**Crater E**	**Crater F**	**cave**
sampling date	21.07.99	21.07.99	21.07.99	21.07.99	21.07.99	21.07.99
As (total) Ext. I	0.006	0.009	0.013	0.013	0.012	0.01
As (total) Ext. II	0.008	0.006	0.014	0.011	0.013	0.009
As (total) [ug/L] HCC	3.227	3.4575	6.2235	5.532	5.7625	4.3795
As(total) [ug/L] LCC	4.175	4.469	7.997	7.115	7.409	5.645
As [ug/L] [laborato-ry]	8.20	8.66	8.57	8.55	8.57	8.25
difference HCC-lab [ug/L]	-4.97	-5.20	-2.34	-3.01	-2.81	-3.87
difference LCC-lab [ug/L]	-4.03	-4.19	-0.57	-1.43	-1.16	-2.60

App.No.36.: Characterization and limitations for the analyzed elements

(MORT = mean ocean residence time in years, SE = seawater enrichment)

element	characterization (MERKEL & SPERLING 1998, if not otherwise cited)	stream water, sea water, SE and MORT (FAURE 1991)	limitations	NORMA Mexicana 1994
pH			6.5-9.5 (TrinkwV 1990)	6.5 - 8.5
temp.			25°C (TrinkwV 1990)	
cond.			2000µS/cm (TrinkwV 1990)	
oxygen			5mg/L O_2 (TrinkwV 1990)	
Na	surface water 0.1-1540mg/L, groundwater 0.1-1810mg/L, higher in semiarid and arid areas with high evaporation and in evaporitic rocks	$3*10^{-3}$ mg/kg, $1.7*10^{-1}$ mg/kg, 56.7 $2.5*10^{6}$a	150mg/l (TrinkwV 1990)	200
K	ratio Na:K = 2:1 - 10:1, surface water 6.5mg/L, groundwater 0.1-98mg/L (depending on the aquifer: sediments 1-4mg/L, limestone / dolomite 0.7-4mg/L, hard rock 1-8mg/L)	2.3 mg/kg, $3.99*10^{2}$ mg/kg, 173 $1.3*10^{7}$a	12mg/L (TrinkwV 1990)	
Ca	surface water ∅ 15mg/L (4-40mg/L), groundwater (depending on the aquifer: sediments 35-120mg/L, limestone / dolomite 65-130mg/L, hard rock 20-75mg/L, carbonates 60-100mg/L), under higher partial pressures (e.g. from volcanic sources) concentrations up to 300mg/L possible, in contact with gypsum 600mg/L ($CaSO_4$ limiting phase),	15 mg/kg, $4.13*10^{2}$ mg/kg, 27.5 $1.3*10^{6}$a	400mg/L (TrinkwV 1990)	
Mg	surface water ∅ 4mg/L (0-50mg/L), groundwater (depending on the aquifer: sediments 4-25mg/L, limestone / dolomite 7-40mg/L, hard rock 7-35mg/L)	4.1 mg/kg, $1.29*10^{3}$ mg/kg, 315 $5.0*10^{7}$a	50mg/L (TrinkwV 1990)	
HCO_3	groundwater (depending on the aquifer: sediments 80-350mg/L, limestone / dolomite 210-390mg/L, hard rock 70-350mg/L)			
CO_2	groundwater (depending on the aquifer: sediments <0.1-35mg/L, limestone / dolomite <0.1-1mg/L, hard rock <0.1-22mg/L)			
SO_4	surface water 10-150mg/L , groundwater (depending on the aquifer: sediments 15-105mg/L, limestone / dolomite 20-125mg/L, hard rock 7-75mg/L), significantly higher under gypsum or anhidrite influence, man made source: pesticides and fertilizers	S: 3.7 mg/kg, $9.0*10^{2}$ mg/kg, 243 $5.0*10^{8}$a	240mg/L (TrinkwV 1990)	400
PO_4	groundwater ∅ 0.06mg/L, higher in thermal and mineral waters (few mg/L), man made mostly from fertilizers	P: $2*10^{-2}$ mg/kg, $7.1*10^{-2}$ mg/kg, 3.6 $4.0*10^{4}$a	>1mg/L eutrophy danger increases for surface water (MERKEL & SPERLING 1998), 5mg/L P_2O_5 drinking water standard (European Community), 6.7mg/l PO_4^{3-} (TrinkwV 1990)	
N-NO_2	groundwater (depending on the aquifer: sediments <10-30mg/L, limestone / dolomite <10mg/L, hard rock <10mg/L)		0.1mg/L (TrinkwV 1990)	0.05
N-NO_3	rivers 1mg/L (upstream) - 20mg/L (downstream), groundwater (depending on the aquifer: sediments 0.4-30mg/L, limestone / dolomite 4-35mg/L, hard rock 0.2-25mg/L)		50mg/L as NO_3 (TrinkwV 1990)	10 as N-NO_3
N-NH_3	high NH_4^{+} contents possible in thermal waters influenced by volcanic processes, groundwater (depending on the aquifer: sediments <0.01-0.3mg/L, limestone / dolomite <0.01-0.02mg/L, hard rock <0.01-0.1mg/L)		0.5mg/l (TrinkwV 1990)	0.5

element	**characterization** (MERKEL & SPERLING 1998, if not otherwise cited)	stream water, sea water, SE and MORT (FAURE 1991)	limitations	NORMA Mexicana 1994
Cl	groundwater <30mg/L, saline deposits 100mg/L or more, also increased due to precipitation especially in marine environments, man made source: fertilizers	7.8 mg/kg, $1.95*10^4$ mg/kg, 2500 $6.3*10^8$a	250 mg/L (TrinkwV 1990)	
F	fresh water <1mg/L, mineral waters >60mg/L possible, high F contents in mica and clay rich rocks and alcaline volcanic rocks (20-30mg/L)	$1*10^{-3}$ mg/kg, 1.3 mg/kg, 1300 $7.9*10^5$a	1.5mg/L (TrinkwV 1990)	1.5
Si	0.15-0.65mmol/L in surface water, 12-17mg/L groundwater, solubility is temperature and modification dependent (geothermometer)	6.5 mg/kg, 2.8 mg/kg, 0.43 $7.9*10^3$a		
Li	surface water 0.1-400µg/L, median 1µg/L, thermal water 2-5mg/L from mica weathering, brines 0.04-100mg/L, high contents in magmatites (especially granites and rhyolithes)	$3*10^{-3}$ mg/kg, $1.7*10^{-1}$ mg/kg, 56.7 $2.5*10^6$a	citrus fruits relative sensitiv (0.06-0.1mg/L) (MERKEL & SPERLING 1998), no limitations in drinking water standard (Germany and USA)	
B	5-1000mg/L in hydrothermal zones and arid evaporation basins, rivers 0.01mg/L, groundwater a few to 65 µg/L	$1*10^{-2}$ mg/kg, 4.5 mg/kg, 450 $1.6*10^7$a	>1mg/L in irrigation water is toxic for citrus fruits (MERKEL & SPERLING 1998), 1mg/L (TrinkwV 1990)	
Al	1/100 to a few tens of mg/L in fresh and groundwater, higher in acid waters and soil with weak buffer system	$5*10^{-2}$ mg/kg, $8*10^{-4}$ mg/kg, 0.016 7.0a	0.2mg/L (TrinkwV 1990) water 5mg/L for watering animals (MERKEL & SPERLING 1998)	0.20
Mn	rivers 0.05mg/L, man made source: fertilizers, fungicides, fodder additif but normally the compartments water and soil seem to be independent of man made Manganese influence, median in Norwegian hard rock groundwater 7.5µg/L (REIMANN et al. 1996)	$7*10^{-3}$ mg/kg, $3*10^{-4}$ mg/kg, 0.04 $3.2*10^1$a	0.05mg/L (TrinkwV 1990)	0.15
Fe	1-10mg/L in groundwater with pH 5-9, pH>9 only traces (<0.5mg/L)	$4*10^{-2}$ mg/kg, $6*10^{-5}$ mg/kg, 0.0015 $6.9*10^{-1}$a	0.2mg/L (TrinkwV 1990)	0.3
Cr	river 0-114µg/l (∅ 1µg/L), groundwater <10µg/L, high in alcaline and ultraalcaline magmatites often with Ni and Mg from the early phase of mineralization in magma differentiation, in biotite and Mg-rich amphiboles, man made sources: fertilizers, normally absorbed in soil but due to low buffer capacity transport to groundwater possible, median in Norwegian hard rock groundwater 0.54µg/L (REIMANN et al. 1996) granite 1-5mg/kg, tuff 24-70mg/kg, basalt 253-398mg/kg, claystone 97-110mg/kg, limestone 2-9mg/kg, sandstone 9-30mg/kg, sand 1-2mg/kg (HAUENSTEIN & HUTZLER-GARDT 1996)	$1*10^{-3}$ mg/kg, $2*10^{-4}$ mg/kg, 0.2 $1.6*10^3$a	0.05mg/L (TrinkwV 1990) 0.1mg/L drinking water standard (USA) 100mg/kg standard in soils, intervention value 380mg/kg (NIEDERLÄNDISCHE LISTE 1994)	0.05
Co	ratio Co:Ni=1:4, surface water ∅ 0.19µg/L, groundwater 0.01-20 µg/L, associated with Fe-, Mn-oxides and silicates (biotite), little solubility, readily absorbed	$1*10^{-4}$ mg/kg, $2*10^{-6}$ mg/kg, 0.02 $2*10^1$a	no limitations from WHO and European Community	

element	**characterization** (MERKEL & SPERLING 1998, if not otherwise cited)	**stream water, sea water, SE and MORT** (FAURE 1991)	**limitations**	**NORMA Mexicana** 1994
Ni	surface water 4-14µg/L, groundwater 3-130µg/L, higher in alcaline and ultraalcaline magmatites from olivine weathering, readily released in weathering processes, but normally also rapidly absorbed again on Fe-, Mn-oxides granite 4-19mg/kg, tuff 13-27mg/kg, basalt 154-278mg/kg, claystone 55-65mg/kg, limestone 12-22mg/kg, sandstone 10-18mg/kg, sand 4-7mg/kg (HAUENSTEIN & HUTZLER-GARDT 1996)	$3*10^{-4}$ mg/kg, $5*10^{-4}$ mg/kg, $1.6*10^{3}$a	0.05mg/L (TrinkwV 1990), 0.02mg/L (European Community) 35mg/kg standard in soils, intervention value 210mg/kg (NIEDERLÄNDISCHE LISTE 1994)	
Cu	1-7µg/l in surface water, groundwater 1-12µg/L, associated with suflur, in hydrothermal veins and impregnations, in soil bound to organic rich horizons, man made sources: pesticides and other agrochemicals, often liquid manure due to Cu enriched food granite 2-10mg/kg, tuff 7-11mg/kg, basalt 38-67mg/kg, claystone 19-26mg/kg, limestone 7-12mg/kg, sandstone 6-11mg/kg, sand <3mg/kg (HAUENSTEIN & HUTZLER-GARDT 1996)	$7*10^{-3}$ mg/kg, $3*10^{-4}$ mg/kg, 0.04 $1.0*10^{3}$a	3mg/L (TrinkwV 1990), 2mg/L (WHO), 0.5mg/L water for watering animals, irrigation water <0.2mg/L (MERKEL & SPERLING 1998) 36mg/kg standard in soils, intervention value 190mg/kg (NIEDERLÄNDISCHE LISTE 1994)	2
Zn	0-450µg/L (∅<10µg/L), surface water up to 10µg/L granite 8-121mg/kg, tuff 80-220mg/kg, basalt 90-117mg/kg, claystone 88-108mg/kg, limestone 26-46mg/kg, sandstone 22-39mg/kg, sand 9-13mg/kg (HAUENSTEIN & HUTZLER-GARDT 1996)	$2*10^{-2}$ mg/kg, $4*10^{-4}$ mg/kg, 0.02 $1.3*10^{3}$a	5mg/L (TrinkwV 1990) 140mg/kg standard in soils, intervention value 720mg/kg (NIEDERLÄNDISCHE LISTE 1994)	5
Cd	river and groundwater <5µg/L, mostly less than 1µg/L, median in Norwegian hard rock groundwater 0.032µg/L (REIMANN et al. 1996) granite 0.09-0.20mg/kg, tuff <0.3mg/kg, basalt 0.13-0.22mg/kg, claystone 0.13mg/kg, limestone 0.04-0.05mg/kg, sandstone 0.05mg/kg, sand <0.3mg/kg (HAUENSTEIN & HUTZLER-GARDT 1996)	$1*10^{-5}$ mg/kg, $8*10^{-5}$ mg/kg, 8 $7.9*10^{4}$a	0.005mg/L (TrinkwV 1990) 0.8mg/kg standard in soils, intervention value 12mg/kg (NIEDERLÄNDISCHE LISTE 1994)	0.005
As	surface water 0.15-0.45µg/L, groundwater 5-50µg/L, thermal water 20-3800mg/L, median in Norwegian hard rock groundwater 0.2µg/L (REIMANN et al. 1996) granite 1.2-2.9mg/kg, tuff 3.1-8.5mg/kg, basalt 1.6-4.3mg/kg, claystone 7.4-10.8mg/kg, limestone 2.5-5.3mg/kg, sandstone 3.6-6.3mg/kg, sand 1.1-1.5mg/kg (HAUENSTEIN & HUTZLER-GARDT 1996)	$2*10^{-3}$ mg/kg, $1.7*10^{-3}$ mg/kg, 0.85 $1.0*10^{5}$a	0.01mg/L (TrinkwV 1990), 1mg/L irrigation water (MERKEL & SPERLING 1998) 29mg/kg standard in soils, intervention value 55mg/kg (NIEDERLÄNDISCHE LISTE 1994)	0.05
Se	surface water 0.06-0.33µg/L, groundwater 0.1-0.2µg/L (higher values up to 135µg/L probably already man made), increased in magmatic and hydrothermal zones, in marine sediments high Se contents in rock and soil, under aride conditions and artificial irrigation outwash of Se possible, San Joaquin Valley (California) problems with animals after watering with Se-bearing water	$6*10^{-5}$ mg/kg, $1.3*10^{-4}$ mg/kg, 2.2 $6.3*10^{5}$a	0.01mg/L (TrinkwV 1990), 0.05mg/L (USA)	
Sr	ratio Sr/Ca = $4.8*10^{-3}$, surface water 68.5µg/L, groundwater 0.01-1mg/L, high contents in feldspates, evaporites (1000-2400mg/kg) and carbonates (200-9700mg/kg), close relations to K and Ca	$7*10^{-2}$ mg/kg, 7.6 mg/kg, 109 $5.0*10^{6}$a	USA, Germany, EC no limitations since non-radioactive Sr presents no toxicity (MERKEL & SPERLING 1998)	
Sb	surface water 0.05-0.08µg/L, groundwater <1µg/L, mostly <0.1µg/L, hydrothermal springs often 8-1000µg/L, often correlating with As	$7*10^{-5}$ mg/kg, $1.5*10^{-4}$ mg/kg, 2.1 $1.3*10^{5}$a	Germany no limitations, 6µg/L drinking water standard (USA)	

element	**characterization** (MERKEL & SPERLING 1998, if not otherwise cited)	**stream water, sea water, SE and MORT** (FAURE 1991)	**limitations**	**NORMA Mexicana** 1994
Ba	surface water few to 200µg/L, groundwater 1-22900µg/L (∅ 1-2µg/L), high in K-feldspate rich sandstones (5-900mg/kg) and carbonates (90mg/kg), corresponding sulfate contents decisive ($BaSO_4$ limiting mineral phase)	$2*10^{-2}$ mg/kg, $1.4*10^{-2}$ mg/kg, 0.7 $5.0*10^{3}$a	1mg/L (TrinkwV 1990), 0.1mg/L (WHO and EC), USA no limitations	0.7
Sc	median in Norwegian hard rock groundwater 1.96µg/L (REIMANN et al. 1996)	$4*10^{-6}$ mg/kg, $6.7*10^{-7}$ mg/kg 0.17 $2.5*10^{1}$a		
Y	median in Norwegian hard rock groundwater 0.14µg/L (REIMANN et al. 1996)	$4.5*10^{-5}$ mg/kg, $7*10^{-6}$ mg/kg, 0.18 $1.3*10^{2}$a		
La	median in Norwegian hard rock groundwater 0.145µg/L (REIMANN et al. 1996)	$4.8*10^{-5}$ mg/kg, $4.5*10^{-6}$ mg/kg, 0.094 $7.9*10^{1}$a		
Ce	MARTIN (1996): 3 measurements in mining gallery waters (Freiberg, Germany) 0.17µg/L, 8.1µg/L, 233µg/L HENCKE (1998): 21-43µg/L in dam water (Germany), median in Norwegian hard rock groundwater 0.147µg/L (REIMANN et al. 1996)	---		
Pr	median in Norwegian hard rock groundwater 0.0395µg/L (REIMANN et al. 1996)	$7.3*10^{-6}$ mg/kg, $1.0*10^{-6}$ mg/kg 0.14 $7.9*10^{1}$a		
Nd	median in Norwegian hard rock groundwater 0.155µg/L (REIMANN et al. 1996)	$3.8*10^{-5}$ mg/kg, $4.2*10^{-6}$ mg/kg, 0.11 $7.9*10^{1}$a		
Sm	median in Norwegian hard rock groundwater 0.028µg/L (REIMANN et al. 1996)	$7.8*10^{-6}$ mg/kg, $8.0*10^{-7}$ mg/kg 0.10 $7.9*10^{1}$a		
Eu	median in Norwegian hard rock groundwater 0.011µg/L (REIMANN et al. 1996)	$1.5*10^{-6}$ mg/kg, $1.5*10^{-7}$ mg/kg, 0.10 $6.3*10^{1}$a		
Gd	median in Norwegian hard rock groundwater 0.029µg/L (REIMANN et al. 1996)	$8.5*10^{-6}$ mg/kg, $1.0*10^{-6}$ mg/kg 0.11 $1.0*10^{2}$a		
Tb	median in Norwegian hard rock groundwater 0.004µg/L (REIMANN et al. 1996)	$1.2*10^{-6}$ mg/kg, $1.7*10^{-7}$ mg/kg, 0.14 $1.0*10^{2}$a		
Dy	median in Norwegian hard rock groundwater 0.021µg/L (REIMANN et al. 1996)	$7.2*10^{-6}$ mg/kg, $1.1*10^{-6}$ mg/kg, 0.15 $1.0*10^{2}$a		
Ho	median in Norwegian hard rock groundwater 0.0045µg/L (REIMANN et al. 1996)	$1.4*10^{-6}$ mg/kg, $2.8*10^{-7}$ mg/kg, 0.20 $1.3*10^{2}$a		

element	**characterization** (MERKEL & SPERLING 1998, if not otherwise cited)	**stream water, sea water, SE and MORT** (FAURE 1991)	**limitations**	**NORMA Mexicana** 1994
Er	median in Norwegian hard rock groundwater 0.0155µg/L (REIMANN et al. 1996)	$4.2*10^{-6}$ mg/kg, $9.2*10^{-7}$ mg/kg, 0.22 $1.6*10^{2}$a		
Tm	median in Norwegian hard rock groundwater 0.002µg/L (REIMANN et al. 1996)	$6.1*10^{-7}$ mg/kg, $1.3*10^{-7}$ mg/kg, 0.21 $1.6*10^{2}$a		
Yb	median in Norwegian hard rock groundwater 0.014µg/L (REIMANN et al. 1996)	$3.6*10^{-6}$ mg/kg, $9.0*10^{-7}$ mg/kg, 0.25 $2.0*10^{2}$a		
Lu	median in Norwegian hard rock groundwater 0.003µg/L (REIMANN et al. 1996)	$6.4*10^{-7}$ mg/kg, $1.4*10^{-7}$ mg/kg, 0.22 $2.0*10^{2}$a		
Tl	surface water ∅ 0.04µg/L (NRIAGU (1998): ∅ 0.02µg/L), groundwater 0.02-9,5µg/L (NRIAGU (1998): ∅ 7.25µg/L)	--- mg/kg, $1*10^{-5}$ mg/kg, --- $6.3*10^{3}$a	no limitations Germany and EPA	
Pb	surface water 1-55µg/L, up to 9µg/L in groundwater (∅ 1.9), higher with low pH and low HCO_3^- contents granite 9-72mg/kg, tuff 19-40mg/kg, basalt 26-37mg/kg, claystone 34-46mg/kg, limestone 32-45mg/kg, sandstone 16-25mg/kg, sand 9-12mg/kg (HAUENSTEIN & HUTZLER-GARDT 1996)	$1*10^{-3}$ mg/kg, $2*10^{-6}$ mg/kg, 0.002 $5.0*10^{1}$a	0.04mg/L (TrinkwV 1990) 85mg/kg standard in soils, intervention value 530mg/kg (NIEDERLÄNDISCHE LISTE 1994)	0.025
Th	groundwater 0.007-0.1µg/L (median 0.03), river 0.1-2.7µg/L, especially in silicate rocks	$<1*10^{-4}$ mg/kg, $6*10^{-8}$ mg/kg, ~ 0.0006 3.4a	no limitations known, danger from Th in water is very small due to little solubility (MERKEL & SPERLING 1998)	
U	surface water 0.03-3.9µg/L, groundwater 0.2-2.2µg/L, (SCOTT & BARKER (1962): up to 120µg/L in the area between Missouri and Missisippi in USA due to intensive granite weathering and volcanic ash probably being the source for uranium ore deposits), also increased due to uranium bearing phosphatic fertilizers (30-200mgU/kg P, but until now not proofed as groundwater contamination source, only in surface water and soils), in tailing water from uranium processing 1-15mg/L	$4*10^{-5}$ mg/kg, $3.1*10^{-3}$ mg/kg, 2.7 $1*10^{6}$a	20 µg/L drinking water standard (USA) (just for radiological reasons, no chemical toxicity known) α-activity = 0,1Bq/L, β-activity = 1.0Bq/L, 7000mBq/L U_{nat} (300µg/L) (WHO limits for drinking water) (MERKEL & SPERLING 1998)	α-ctivity = 0.1Bq/L β-activity = 1.0Bq/L
total organic coliforms				2 NMP/ 100ml, 2 UFC/ 100ml
fecal organic coliforms				0 UFC and NMP/ 100ml
pesticides			0.5µg/L total, 0.1 µg/L for each substance (TrinkwV 1990)	