STRATIGRAPHY AND URANIUM POTENTIAL OF THE LA QUINTA FORMATION OF JURASSIC AGE, NORTH-CENTRAL TACHIRA, VENEZUELA[1)]

by

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ABSTRACT

This paper presents the results of geologic field work and stratigraphic analysis of four sections of the Jurassic La Quinta Formation measured by the author, and two others, the Pregonero section and the La Quinta type section of the La Quinta Formation, which were taken from the literature. All of these sections are located in the southwestern foothills of the Venezuelan Andes in the north-central part of the State of Tachira. The depositional regime of the La Quinta sedimentary rocks and the possible factors of control on uranium occurrences in the study area are reconstructed.

The La Quinta Formation rests unconformably on Precambrian or Paleozoic igneous-metamorphic rocks and is unconformably overlain by Cretaceous coastal-plain sediments. In the study area, the La Quinta Formation displays variable thickeness from 0 m up to 3,400 m.

The Jurassic sediments of the La Quinta Formation, characterized by detrital deposits of red and/or gray conglomerates, immature or submature medium- to fine-grained arkoses, siltstones, and shales with local limestones, were deposited in an arid or semi-arid climate by braided and meandering streams. The basic sediment source for the La Quinta deposits is similar to the Precambrian-Paleozoic sequences now exposed adjacent to the study area. Additional Mesozoic volcanic and sedimentary sources are also considered.

Based on the great variability in thickness shown by the La Quinta Formation, the upward change in paleocurrent direction displayed by the Angaraveca-El Zumbador and the San Buenas sections, the lack of tuffaceous detritus in the upper portion of the La Quinta type section, the sudden appearance of conglomeratic lenses in the upper interval of the La Pulida section as well as the increase upward in grain size of the sandstones of this section, the La Quinta Formation in the study area has been divided into two informal intervals, lower and upper.

During the deposition of the lower interval, the whole study area constituted a large depositional basin with streams flowing off of the highland areas located to the north, northwest, west, and southwest. These streams were of the braided type in the areas of the Angaraveca-El Zumbador, La Pulida, and Pregonero sections, and the La Quinta type section, grading to a meandering type in the low relief area of the San Buenas section. Therefore, the lower interval was deposited everywhere in the study area, except in the highland mentioned previously. Later during the Jurassic,

tectonic activity produced reactivation of old structures and the formation of new ones which uplifted a west-central block dividing the area into two depositional basins, and producing an "en échelon" fault system in the western portion of the area. This is the structural framework in which the upper interval was deposited.

During this period of tectonic activity, some of the highland areas which did not receive sediments during the deposition of the lower interval were down-dropped and sedimentation began for the first time, whereas other areas, which already contained deposits of the lower interval, either were still receiving sediments or were uplifted and underwent erosion. This sequence of events produced the variability in thickness displayed by this formation. The lithologic characteristics of the upper interval of the analyzed sections indicate that the environment of deposition remained the same, i.e., braided and meandering streams, with changes in the shifting of the main source area to the southwest and in the energy of the streams.

The La Quinta Formation has been suggested as a possible host of uranium due to its depositional characteristics and its source of sediment. This work represents the first real attempt at exploring for uranium in the La Quinta Formation in Venezuela.

In regard to the study area, only two very local radioactive anomalies were detected; one of these anomalies occurs in the La Pulida section associated with copper-stained silty shale of flood plain deposits of the braided-stream facies and another in the San Buenas section associated with carbonaceous sandstones of the meandering-stream facies. Based on these occurrences, possible target areas are suggested. Finally, some general recommendations are made to guide future exploration.

INTRODUCTION

Purpose

The purpose of this study is to describe the stratigraphy, sedimentology and depositional history of the strata of the La Quinta Formation of Jurassic age, which are principally red nonmarine deposits, in an outcrop area comprising the north-central part of the State of Tachira, southwestern Venezuela (Figure 1). An additional objective is to determine possible favorable areas for uranium mineralization within the La Quinta beds in this area.

Although numerous studies have been conducted dealing with the stratigraphy of the La Quinta Formation in the many places where the formation crops out, this report is the first work that attempts to integrate the stratigraphic data and investigates favorability of and potential of uranium occurrences in the La Quinta Formation in the north-central portion of the State of Tachira.

Location of the Study Area

The location of the measured sections and the State of Tachira are shown in Figure 2. The area lies in the southwestern foothills of the Venezuelan Andes.

Topography and Climate

Elevation within the study area range from 700 m to 3,000 m above sea level. This high relief of the report area results in two distinct types of climate and vegetation. At elevations less than approximately 2,000 m, the climate is tropical with an average annual temperature of 30°C and with precipitation averaging 1,500 mm per year. The vegetation is very densely overgrown rainforest; the weathering is dominately chemical. The finding of good rock exposures is difficult because either the rocks are covered or badly weathered.

At elevations around 3,000 m, the climate is temperate with an average annual temperature of 15°C and with precipitation averaging 1,000 mm per year. The vegetation consists of widely-spaced scrubs; the weathering is a mixture of chemical-mechanical. The fair rock exposures are common.

The lack of continuous outcrops was a major problem of this study.

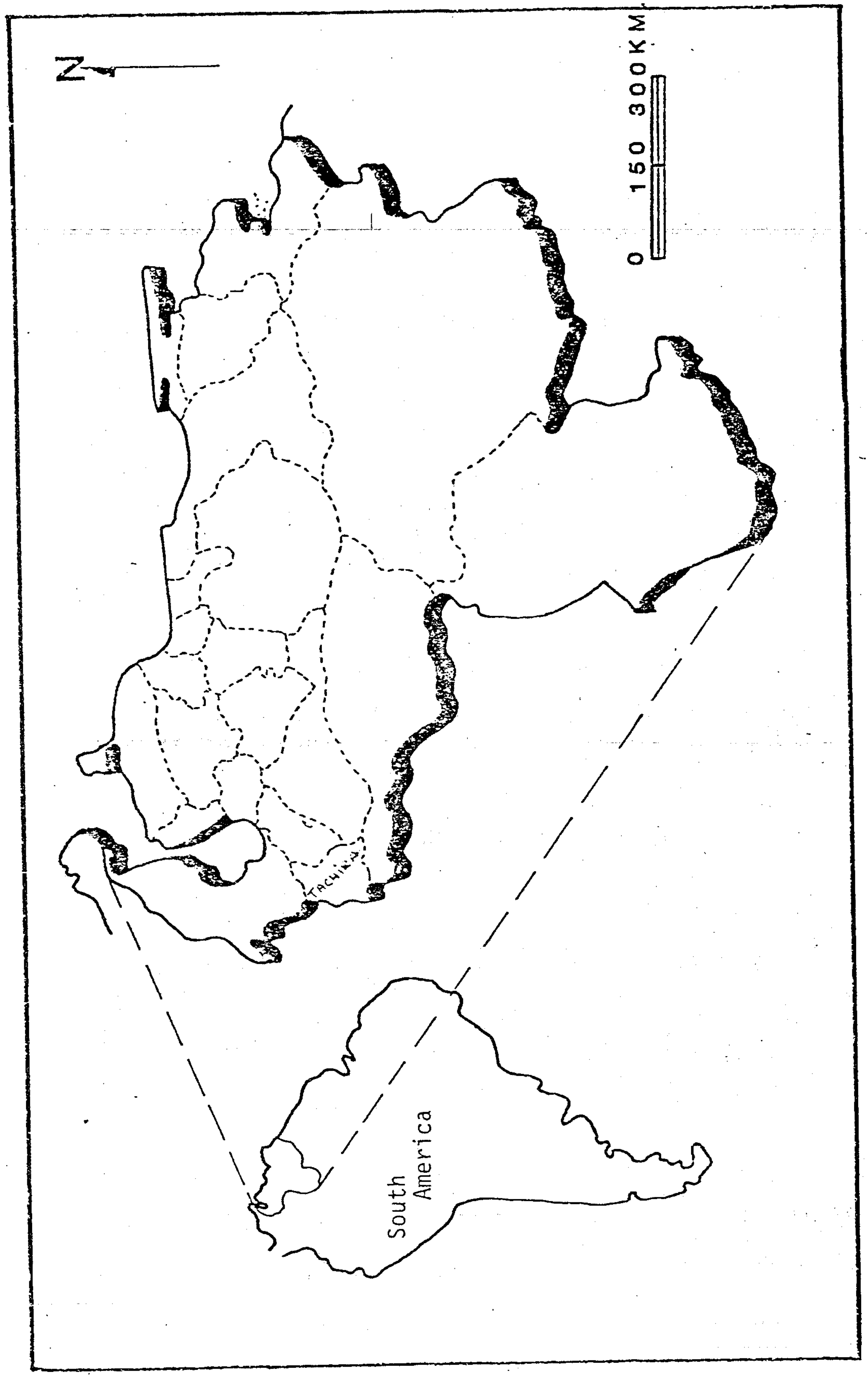


Figure 1 - Location map of Venezuela

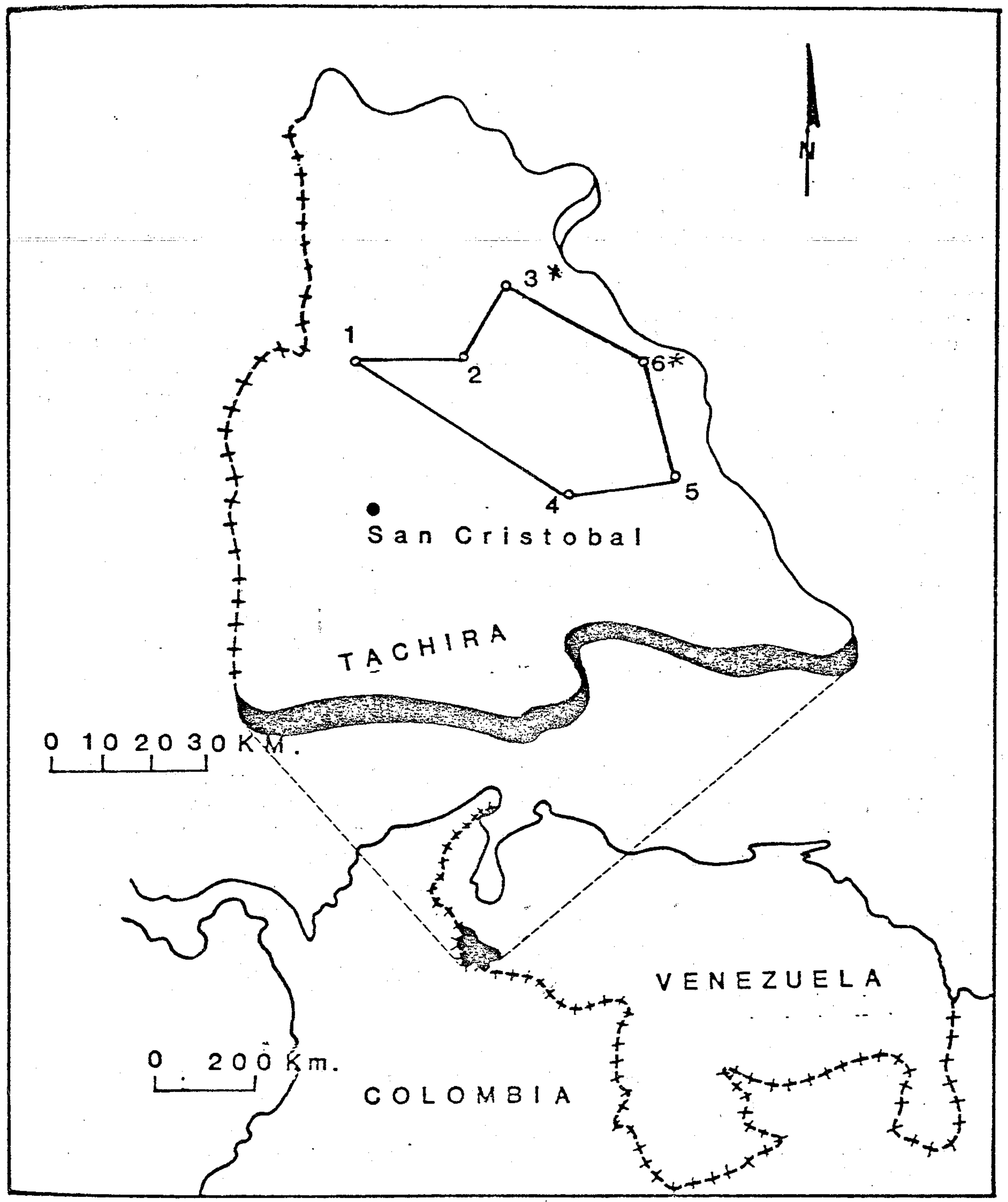


Figure 2.- Location of the area and studied stratigraphic sections within Tachira. 3* and 6* taken from Padron, 1977 and Perez, 1978.

Methods of Study

Field Work

Field work was performed during the summer of 1978. The field work included the measurements of four sections of the La Quinta Formation and a cursory examination of two other sections taken from the literature, the La Quinta type section and the Pregonero section. Analyzed sections are designated: section number 1 - San Juan de Colon; number 2 - Angaraveca-El Zumbador; number 3 - La Quinta type section; number 4 - La Pulida; number 5 - San Buenas and 6 - Pregonero (Figure 2). Where possible, the sections were measured from the top of the underlying Mucuchachi Formation, Carboniferous in age, to the base of the overlying Rio Negro Formation, early Cretaceous in age. Descriptions of hand specimen rock samples, primary and secondary sedimentary structures and outcrop sketches were made in the field.

The thickness of the La Quinta Formation at the studied sections range from up to 1,200 m in the area of San Juan de Colon (number 1) to approximately 3,400 m in the area of Angaraveca-El Zumbador (number 2), but only an average of 25% of each section is exposed.

Laboratory Work

Thin sections were made of some representative samples collected during the field work. Petrographic study consisted of description of grain size variation, matrix, cement and other detrital characteristics of the samples. X-ray analysis was conducted to investigate clay mineral types as an aid to determine environments of deposition. The petrologic names used in this study are based upon the clastic classification system of Pettijohn, Potter and Siever (1972).

The geologic map of the project area (Plate 1) was compiled from a number of sources. However, the primary sources of information were the works of Useche and Fierro (1972), Campos and Vargas (1972) and other unpublished reports. The accompanying geologic maps and structural cross-sections of the San Juan de Colon and Angaraveca-El Zumbador sections (Plates 3 and 4) were compiled utilizing topographic maps of the area at a scale 1:25,000 and all available surface control.

Previous Work

A fair number of geologic investigations have been conducted in the La Quinta Formation. The La Quinta Formation was named and described by Kundig (1938). He described it as a continental sequence of mainly red color, with the "type section" on the road between the town of Seboruco and the village of La Quinta, State of Tachira, Venezuela (Section No. 3, on Figure 2 and Plate 1).

Preceeding 1938, investigations of the La Quinta Formation had been conducted by Sievers (1888), who called it "Old Red Series", and Christ (1927), who called it "Lomita Series". Engleman (1935, cited in Useche and Fierro, 1972) analyzed the "Red Formation" in the Andes with the name "Red Beds of the Permo-Triassic" and postulated them to be a time equivalent with the La Giron Formation (now group) in Colombia. Since Kundig's initial description of the La Quinta Formation (1938), further subdivisions and studies have been conducted by Hedberg (1942) who studied the Mesozoic stratigraphy of northern South America. Gonzales de Juana (1951) in his "Introduction to the Venezuelan Geology" and Bucher (1952) in his work on geologic structure and orogenic history, point out two major areas of the La Quinta outcrops, northeastern outcrop region and southwestern outcrop region separated by a belt 75 km wide and a trend northwest-southeast (Figure 3). Arnold (1961) in his unpublished paper about "The pre-Cretaceous geology of the Venezuelan Andes" studied twelve sections of the La Quinta, among them the type section which he divided into three intervals.

Ramirez and Campos (1972) studied the geology of the Grita-San Cristobal region, Tachira. Also, Useche and Fierro (1972) studied the geology of the Pregonero region, Tachira and Merida. Their works include lithologic descriptions and comments about depositional environments of the La Quinta sediments in those regions. The most recent work has been done as unpublished thesis works by students of the Central University of Venezuela; Loaiza (1978), Padron (1978), Perez (1977), and Velez (1978), who made a general geologic map of different areas in Tachira where the La Quinta Sediments crop out. Padron (1978) restudied the type locality and informally divided it into two intervals, whereas Perez (1977) in the Pregonero section postulated three intervals. Finally, Tremaria (1978) made a study of the La Quinta sediments in the State of Trujillo.

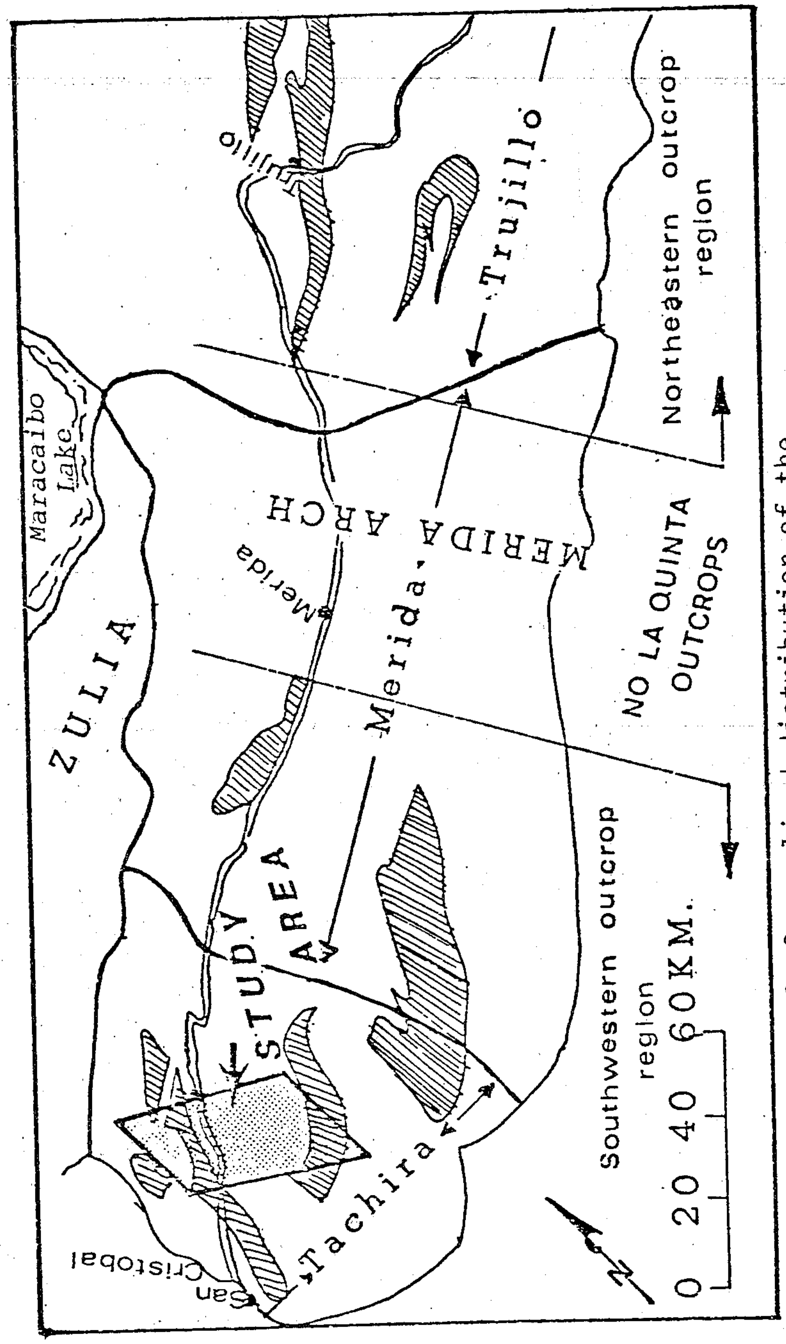


Figure 3.-Generalized distribution of the La Quinta Formation in the Venezuelan Andes. (modified from Hargraves and Shagam, 1969).

LA QUINTA OUTCROPS
STATE BOUNDARIES
HIGHWAY

GEOLOGIC SETTING

Stratigraphy

General Statement

The Jurassic La Quinta sediments unconformably overlie either the Precambrian Iglesias Complex or the Upper Paleozoic Mucuchachi Formation (Plate 1). The La Quinta sequence is overlain unconformably by Cretaceous coastal plain sediments, the Rio Negro Formation.

Iglesias Complex

The "Iglesias Series", as first described by Kundig (1938), consists of highly metamorphosed Proterozoic rocks of igneous and sedimentary origin which constitute the oldest rocks in the Venezuelan Andes. In 1946, Sutton (cited in Useche and Fierro, 1972) defined the type locality of the Iglesias Complex in the peak called Las Iglesias, located in the "Macizos de los Conejos", northwest of the city of Merida, State of Merida, Venezuela. Arnold (1961) used the terms "Sierra Nevada facies" and "Bella Vista facies" for the same rocks. Shagam (1969, cited in Ramirez and Campos 1972) called these metamorphosed Proterozoic rocks the "Iglesias Complex" and distinguished three facies: the Sierra Nevada, Bella Vista and Tostos. The Sierra Nevada facies crops out in the study area and consists of 5-7 km of dominantly quartz-feldspathic meta-sedimentary rocks of amphibolite grade of regional metamorphism (Shagam, 1972). Granitic and pegmatitic intrusions have been by far the dominant type of Precambrian igneous activity.

The sediments of the Iglesias Complex were deposited during the late Precambrian on the western edge of a marine depositional basin (Arnold, 1961).

Mucuchachi Formation

The upper Paleozoic section in the study area is represented by at least 4 km of thickness of a slate sequence of probable marine shale origin. Christ (1927, cited in Comisión Venezolana de Estratigrafía y Terminología, 1970) designated the black locally calcareous or siliceous schists that are exposed close to the town of Mucuchachi, State of Merida, the "Mucuchachi Series". However, it was much later that geologists of Shell of Venezuela and Creole Petroleum Corporation (1946) gave the Mucuchachi a formational status. In general, this unit consists of a sequence of laminated slate, greenish, gray to black, carbonaceous phyllitic slate and interlayers of thin, well-cemented sandstones.

The Mucuchachi Formation (Plate 1) rests upon the Pre-Cambrian rocks of the Iglesias Complex. Its upper contact is transitional to Sabaneta and/or Palmarito Formations. In the study area the Mucuchachi Formation is unconformably overlain by the Jurassic sediments of the La Quinta Formation.

La Quinta Formation

The La Quinta Formation was formally described and named by Kundig (1938) from its type section at the road between the village of the La Quinta and the town of Seboruco, State of Tachira (Section 3 in Figure 2 and Plate 1). Kundig (1928) divided the type section into three informal intervals. The lower interval consists of conglomerates and tuffs with a thickness of approximately 400 m; the middle interval is mainly made up of 500 m of fossiliferous shale. The upper interval consists of 1,300 m of sandstone.

The type section has been redefined two times; the first one by Arnold (1961) and the second one by Padron (1978). Arnold (1961) also divided the section into three informal intervals. However, his thicknesses and lithology for each interval differ from Kundig's description. The lower interval, which he measured as 320 m thick, consists of red and fine-grained tuffs. The middle interval has 350 m of conglomerate and dark brown conglomeratic sandstone with some tuffs, and dark fossiliferous shales. Among the fossils should be mentioned fish teeth, fish scales (Lepidotus), Ostracodes and Cysius. Finally, there is the upper interval, made up of brick-red, well laminated and cross-laminated sandstone.

The last description of the La Quinta Formation at the type section was made by Padron (1978).

Rio Negro Formation

Hedberg (1931, cited in Ramirez and Campos, 1972) named the conglomerate interval at the base of the Cretaceous section in the "La Sierra de Perija", Perija District, State of Zulia, as "Conglomerate of Río Negro". Hedberg and Sass (1937, cited in Comisión Venezolana de Estratigrafía y Terminología,

1970) gave it a formal formational range and described it as white, cross-stratified sandstone with lenses and beds of quartzose conglomerate, with an approximate thickness of 1,500 m. The type section is located in the Negro River, southwest of Machique, Perija District, State of Zulia. Further studies extended this rock unit to the entire western part of Venezuela.

In general, this sequence ranges from white coarse-grained sandstone, heterogeneous conglomerates and yellow, red and purple quartzose, to feldespatic clay and shale.

Maync (1956, cited in Useche and Fierro, 1972, p. 981) considered the Rio Negro Formation as early Aptain or Barremian-Neocomian age due to its stratigraphic position. Maync (1956) and Kiser (1961, cited in Useche and Fierro, 1972) called the Rio Negro Formation, the basal Cretaceous deposit. This formation rests unconformably or conformably on Mesozoic rocks with the upper contact transitional to the Apon Formation. This formation represents the first sediments deposited during the marine transgression that characterized the Cretaceous period in the Western part of Venezuela.

Structural Geology

Gansser (1977) divided the 9,000 km-long Andes Mountain chain into three segments which may be named as follows: Southern or Patagonian Andes, Central or Chilean-Peruvian Andes, and Northern or Ecuatorian-Colombian-Venezuelan Andes.

The study area is located in the Northern Andes, specifically in the southwestern foothills of the Venezuelan Andes (Figure 4). The Venezuelan Andes is an elongate block-uplift system oriented approximately northeast-southwest (Grauch, 1975); they are 400 km long, starting in the vicinity of San Cristobal, Tachira and extending north as far as Barquisimeto, State of Lara. The main structural features in the Venezuelan Andes are horsts and grabens associated with a normal fault pattern in which three directions are predominant: the longitudinal one which trends more or less northeast and two others which cut it at roughly 30 degrees (Mencher, 1963). In spite of the Venezuelan Andes having undergone a long tectonic history extending from the Paleozoic to the Cenozoic, the present structural framework was formed during the Tertiary, corresponding to the Alpine Orogeny. The actual uplift of the Andes began after the Eocene, movement persisting into Miocene to Pliocene when, finally, the Andes were uplifted further to produce the present form.

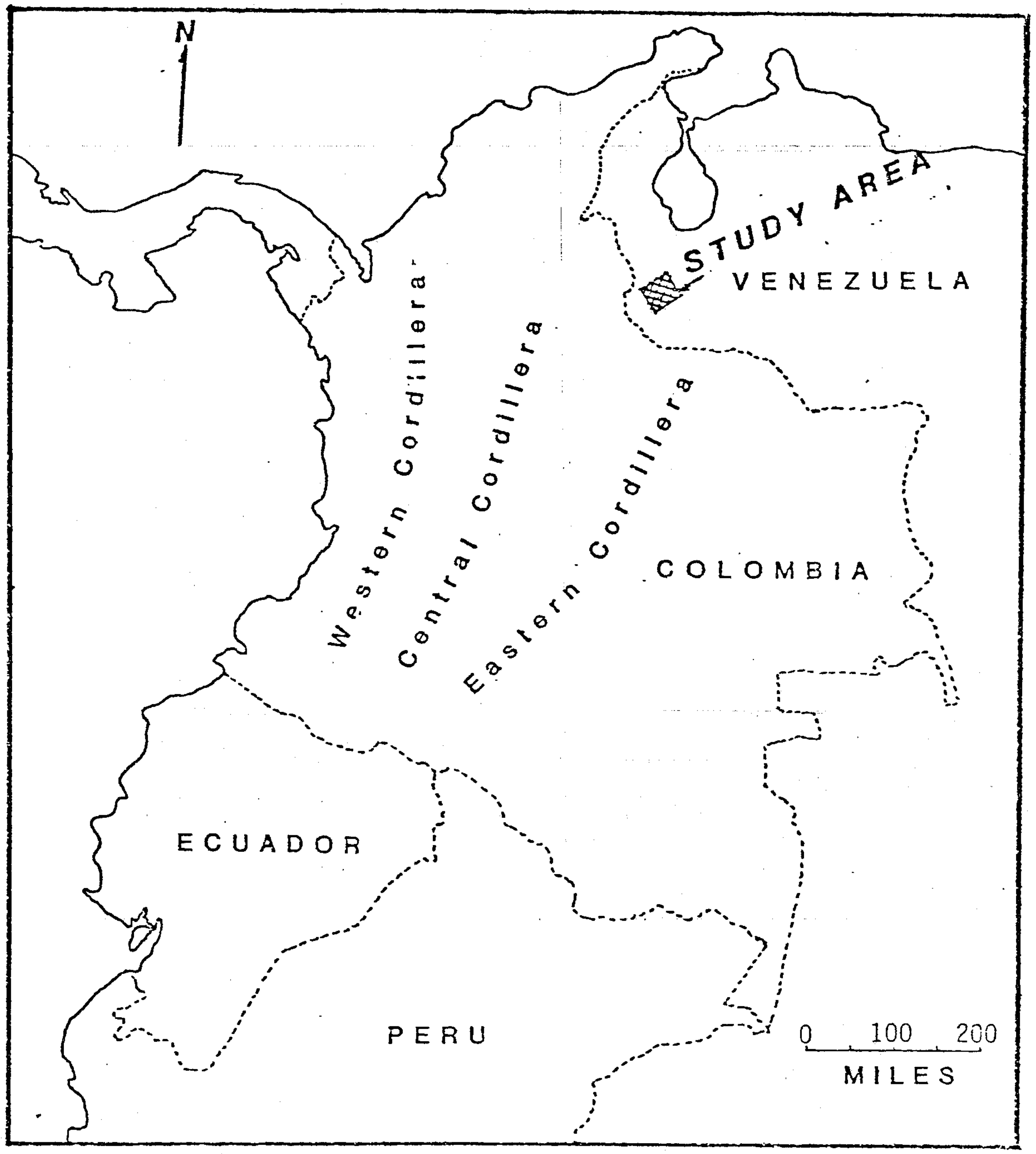


Figure 4 - Location of study area in the Northern Andes (after Von Estorff, 1946).

The principal faults in the study area are the Bocono and the Seboruco (Plate 1), which show mainly vertical movement. The other faults form part of the Bocono fault system trend: northeast-southwest parallel to the axis of the Venezuelan Andes, and mainly consists of high-angle reverse faults and low angle normal faults. Other structures in the area are anticlines and synclines associated with the sedimentary sequences.

LA QUINTA FORMATION

General Statement

The Jurassic sediments of the La Quinta Formation until recently had never been systematically studied and accurately mapped throughout all the area where this formation crops out. General description of its lithology and thickness have been made, but very little is known about the lateral continuity of this sedimentary sequence.

During the field work, four sections of the La Quinta Formation were measured of which two were partial stratigraphic sections with bottom of the sections faulted out. A fifth one (the type section) was taken from Padron's work (1978). Also, the author makes a brief mention of the Pregonero section based on Perez's work (1977).

In the study area the thickness of the La Quinta Formation varies from 0 m to as much as 3,400 m. The La Quinta Formation mainly consists of nonmarine shales, siltstones, sandstones, conglomerates (some of which occur at the base of the section), and local limestones. Most of the rocks in the Angaraveca-El Zumbador and San Juan de Colon sections are red; whereas in the La Quinta type section and the San Buenas and La Pulida sections, both gray and red rocks occur.

Stratigraphic Relationships

Throughout the study area, the La Quinta Formation lies unconformably on the pre-Jurassic rocks, most generally the Carboniferous Mucuchachi Formation and sometimes the Precambrian Iglesias Complex. The contact of the La Quinta Formation with the overlying Cretaceous Rio Negro sediments is unconformable (Plate 1). The bottom of the La Quinta section is faulted at some of the measured stratigraphic sequences (La Pulida and San Buenas sections). At these locations, the faults have put the La Quinta sediments in contact with younger Cretaceous rocks and a part of the La Quinta section is missing.

Lithology

In the following section, lithology descriptions (color, grain size, rock types, and so forth), sedimentary structures,

and paleocurrent directions for each of the studied sections, San Juan de Colon (Section No. 1), Angaraveca-El Zumbador (Section No. 2), La Quinta, type section (Section No. 3), La Pulida (Section No. 4) and San Buenas (Section No. 5) are given.

San Juan de Colon Section (No. 1)

The thickness of this stratigraphic section, obtained from a structural cross-section (Plate 2, Figures 5 and 5a), is approximately 1,270 m, of which 350 m has been eroded.

In general, this section is characterized by red sandstone, even though scattered red conglomerates and thin beds of red shales and siltstones are also present.

Approximately 35% of the San Juan de Colon section (Figure 5) is exposed, characterized from bottom to top by light to dark red, slightly to non-calcareous, fine, medium- or coarse-grained arkosic sandstones; the finer grain size is the most common (Figure 6). Some of these sandstones are cemented by calcite and/or hematite.

Mineralogically, the sandstone contains abundant feldspar (20% to 40%), commonly altered to calcite or sericite. Some feldspars show albite twins. Quartz comprises from 18% to 45% of the rock, shows undulose extinction, and is present only as detrital grains and never as cement. Mica is also abundant (up to 15%) in the arkosic sandstone, the common types are muscovite and biotite. The latter shows golden to dark brown pleochroism. Opaque minerals, ilmenite and hematite occur in abundance up to 10%. The former is sometimes altered to leucoxene. Accessory minerals, such as rutile, zircon, and tourmaline, as well as clay minerals (kaolinite and illite), are also present. Generally, the sandstones are poorly sorted and do not contain abundant matrix clay, except in a few cases where it is up to 35%. Throughout the section, the conglomerate lenses interestratified in some of the sandstone units are of variable thicknesses, from 1.3 to 2.8 m. These conglomerates are poorly sorted and mainly composed of angular to rounded granite fragments and pebble-size quartz and plagioclase, and rarely contain matrix clay.

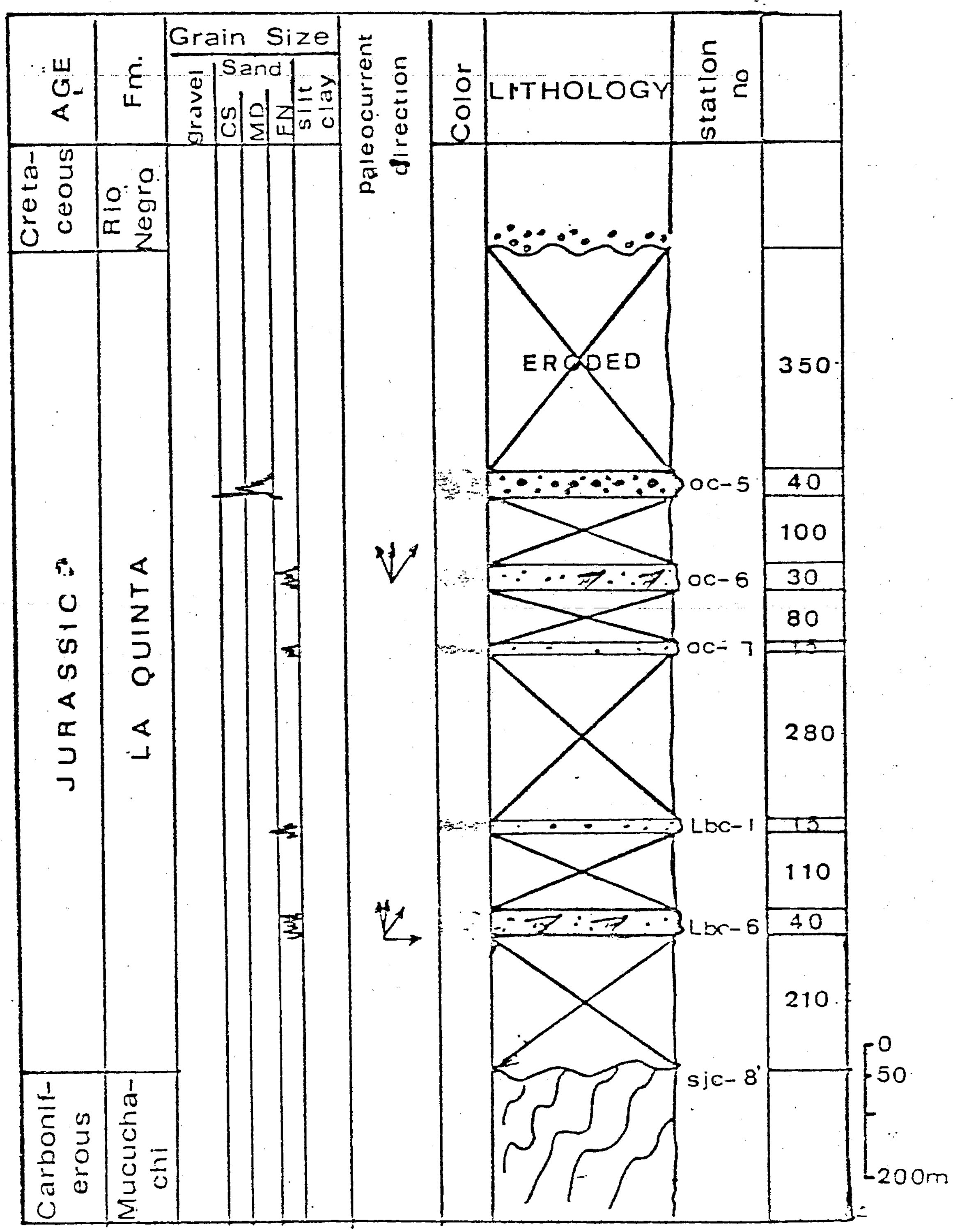
Angaraveca-El Zumbador Section (No. 2).

The La Quinta sediments are folded at the Angaraveca-El Zumbador section (Plate 3) where the approximate thickness of the La Quinta sequence in this area is close to

Figure 5

SAN JUAN DE COLON SECTION

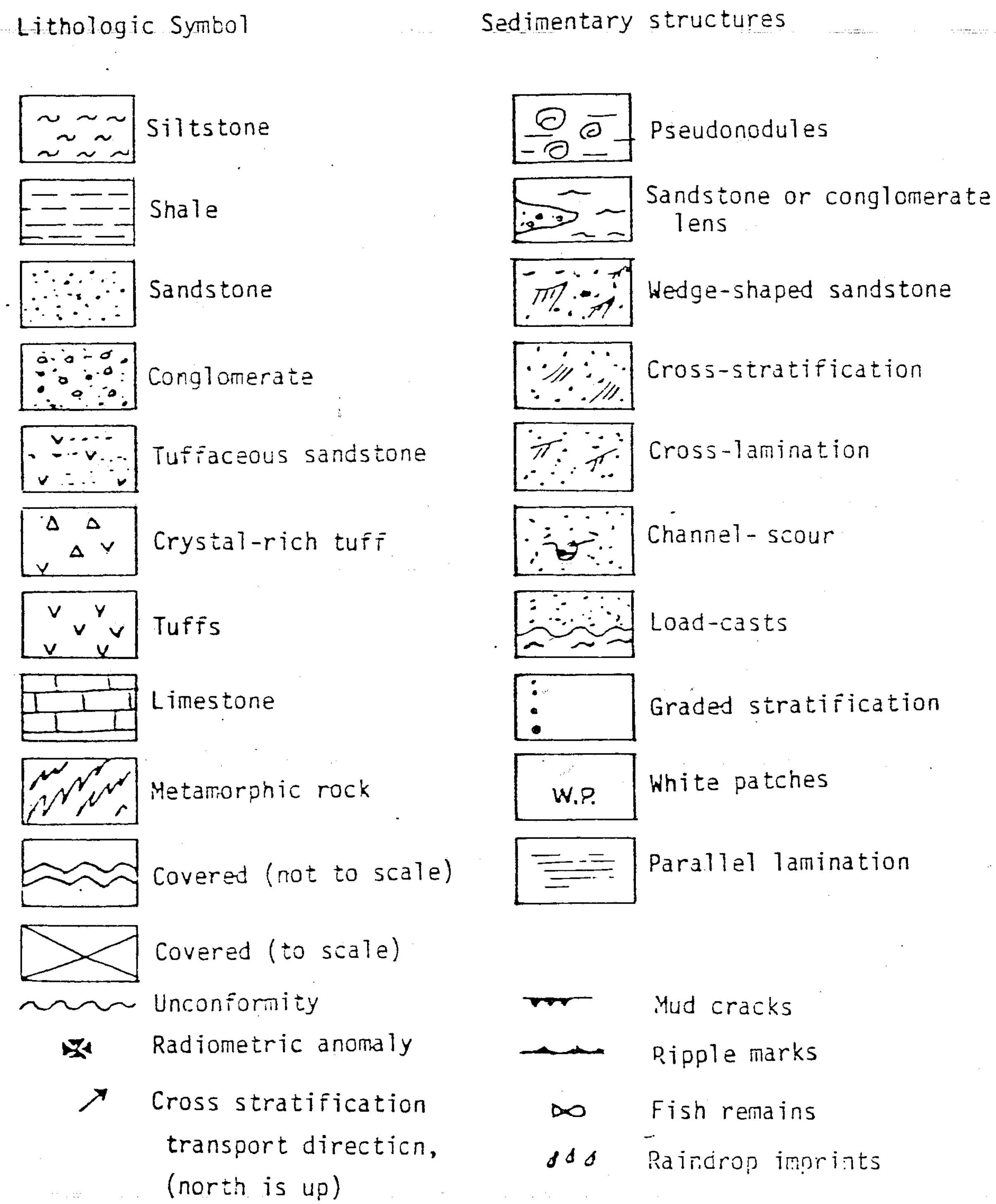
(No 1)



Taken from interpreted cross-section A—A', Plate 2

Figure 5a

EXPLANATION OF LITHOLOGIC SYMBOLS



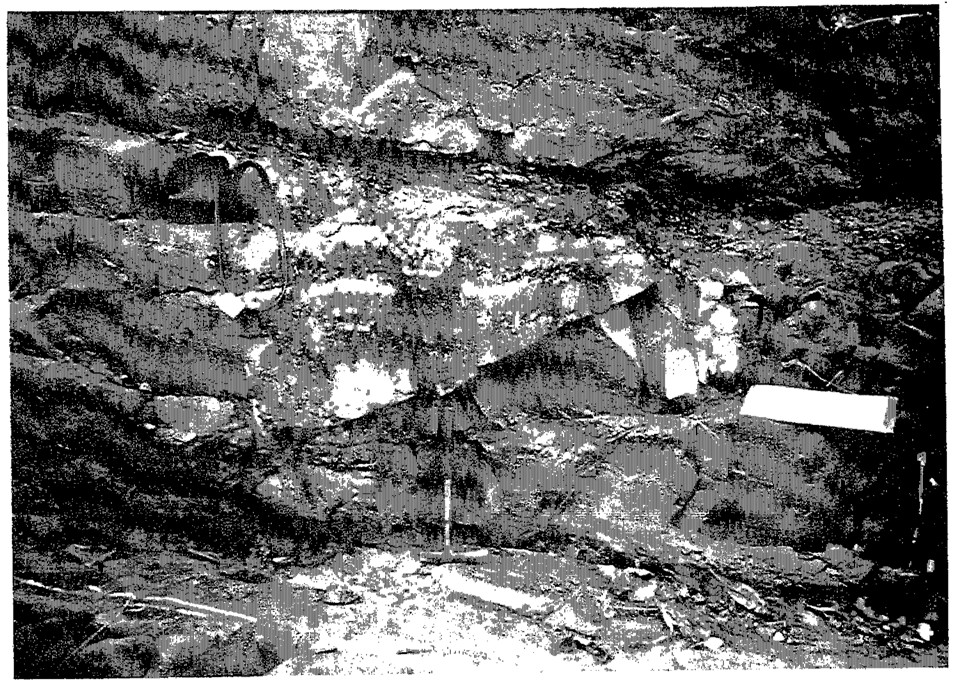


Figure 6. Scour and fill structures within a sandstone unit of La Quinta Formation (San Juan de Colon Section, outcrop SJC-5).

3,400 m (Figure 7), and the whole section is characterized by red colors. This section can be divided into four units. The bottom of this section is made up of a conglomeratic unit approximately 400 m thick. Individual beds of conglomerates have thickness from 3 m up to 12 m and are interestratified with sandstones. The weathered color of the conglomerates and associated sandstones is purple and the fresh color is light gray or whitish. Conglomerate is restricted to the bottom of the section (Plate 3). The conglomerates are composed principally of pebbles of quartzite, phyllite, quartz, granite, biotitic schists and feldspar (plagioclase).

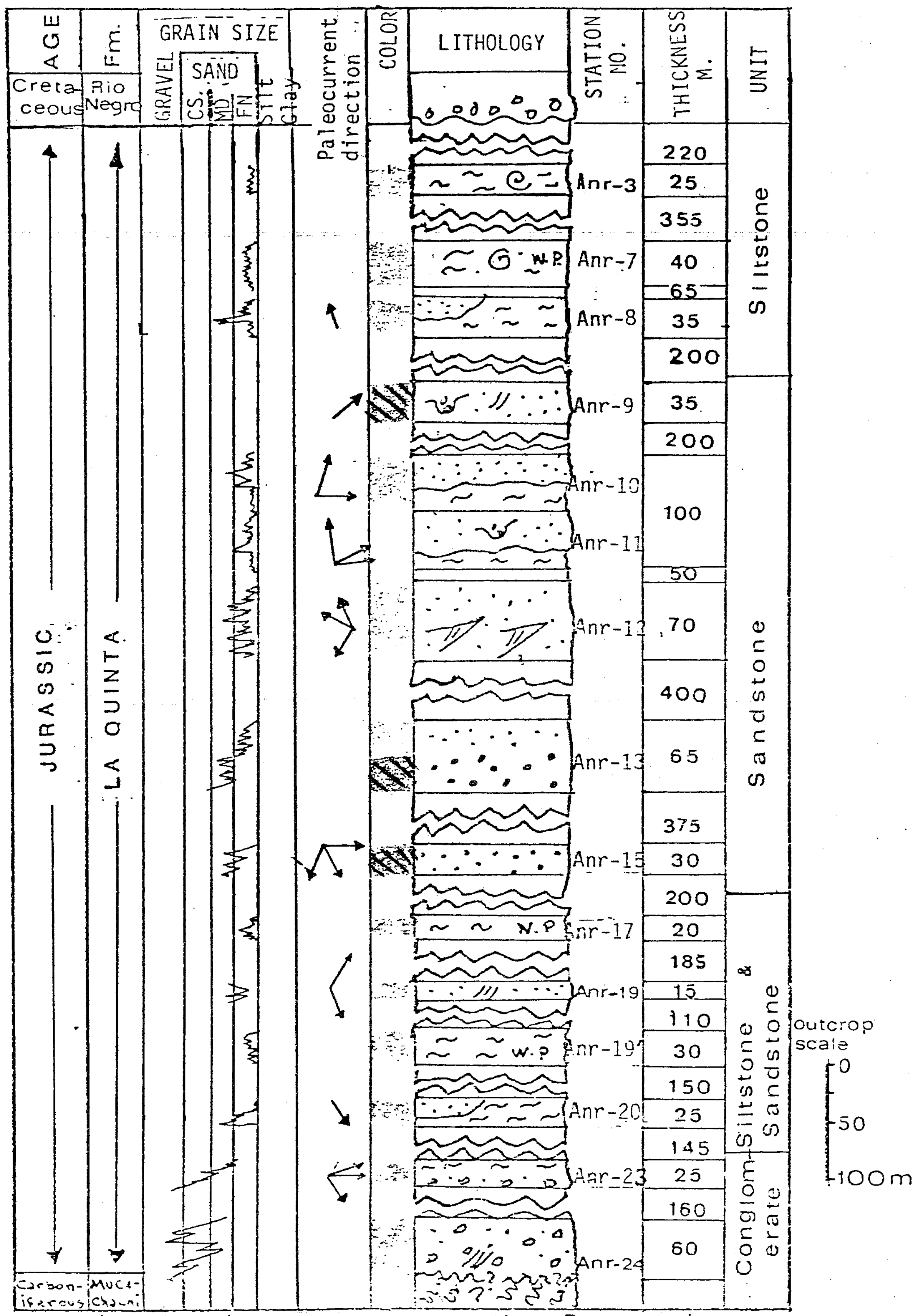
The current bedded conglomerate shows paleocurrent directions which range from N73E to S58E. Moving upward in the section, this unit is vertically followed by a dominately siltstone unit, 400 m thick, which is composed of 83% siltstones and 17% sandstones. The sandstones in this unit are fine-grained and appear as lenses within the siltstones, some of which were deposited as scour and fill deposits and are internally cross-stratified. The individual red beds of siltstone vary in thickness from 1.6 to 7.3 m. This unit is overlain by another 1,600 m thick, made up principally of mostly medium-grained sandstones, although coarse-and fine-grained sandstones are also present in low percentage, the latter becoming more abundant toward the top of the unit. The brown or reddish colored sandstones average 5 m in thickness, with a minimum thickness of 4.3 m and a maximum of up to 14 m. Generally the thick sandstone units are made up of several scour fill sandstone showing graded bedding, or trough or tabular cross-stratification; another common structure are small scale channels. The top of this section consists of a red siltstone-shale unit, 944 m thick, individual siltstone beds averaging 17 m in thickness. The common structures are pseudonodules (Figure 8) and white and greenish patches which are also distributed throughout the section in red fine-grained sediments.

The sandstones are mostly arkosic, ranging from 20 to 45 percent feldspar and from 30 to 60 percent quartz. The quartz has inclusions of tiny crystal of zircon and mica. Some feldspar grains show albite twins and others are altered to sericite. Among the feldspar grains it was possible to identify small amounts of microcline. Ilmenite, leucoxene, and hematite, as well as micas, are other common minerals, but they are less abundant. Hematite is the common cementing material, but calcite is also present in small amounts. The mica types identified were muscovite, biotite and chlorite, the latter two being the least common. The clay minerals were identified as kaolinite and illite. Among the accessory minerals, zircon, epidote and rock fragments were recognized.

Figure 7

ANGARAVECA – EL ZUMBADOR SECTION

(No 2)



Taken from interpreted cross section B—B, Plate 3

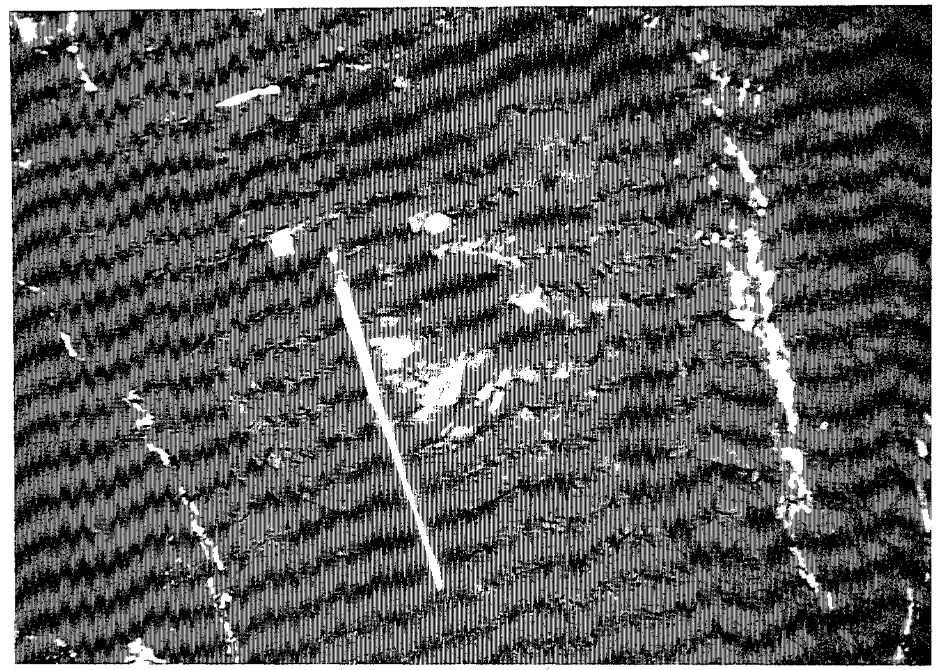


Figure 8. Pseudonodule made of concentric layers of shale, upper interval in Angaraveca-El Zumbador section (outcrop No. Anr-8).

The grains range from angular to rounded, averaging subangular to subrounded; some sand grain size fragments are coated by hematite. The main sedimentary structure present in this section is the cross-stratification in the sandstone. The scour-fill sandstones are internally cross-stratifed (tabular or trough). On the basis of this feature, the paleocurrent directions were determined. The paleocurrents range from easterly, N35E to southerly S25W for the lower 1,480 m and from N83W to east, averaging N10E, for the remaining upper part of the section (Appendix C). Other characteristic sedimentary structures are pseudonodules (Figure 8) formed of concentric layers of shale (common in the fine-grained sediments located at the top of this section, Figure 7). Slight scour surfaces are common at the bottom of the sandstone lenses and parallel lamination are common in some siltstone beds. Throughout the section, the presence of greenish or white, non-calcareous patches in the red colored siltstone bed is common. In a few outcrops, graded and inverted graded stratification were oberved.

La Quinta Type Section

The lithologic description as well as part of the interpretation for this section have been based on the work of Padron (1978) (Figure 9). Generally the author agrees with the lithologic descriptions, but the author differs with regard to his depositional environment interpretation which will be fully described later on.

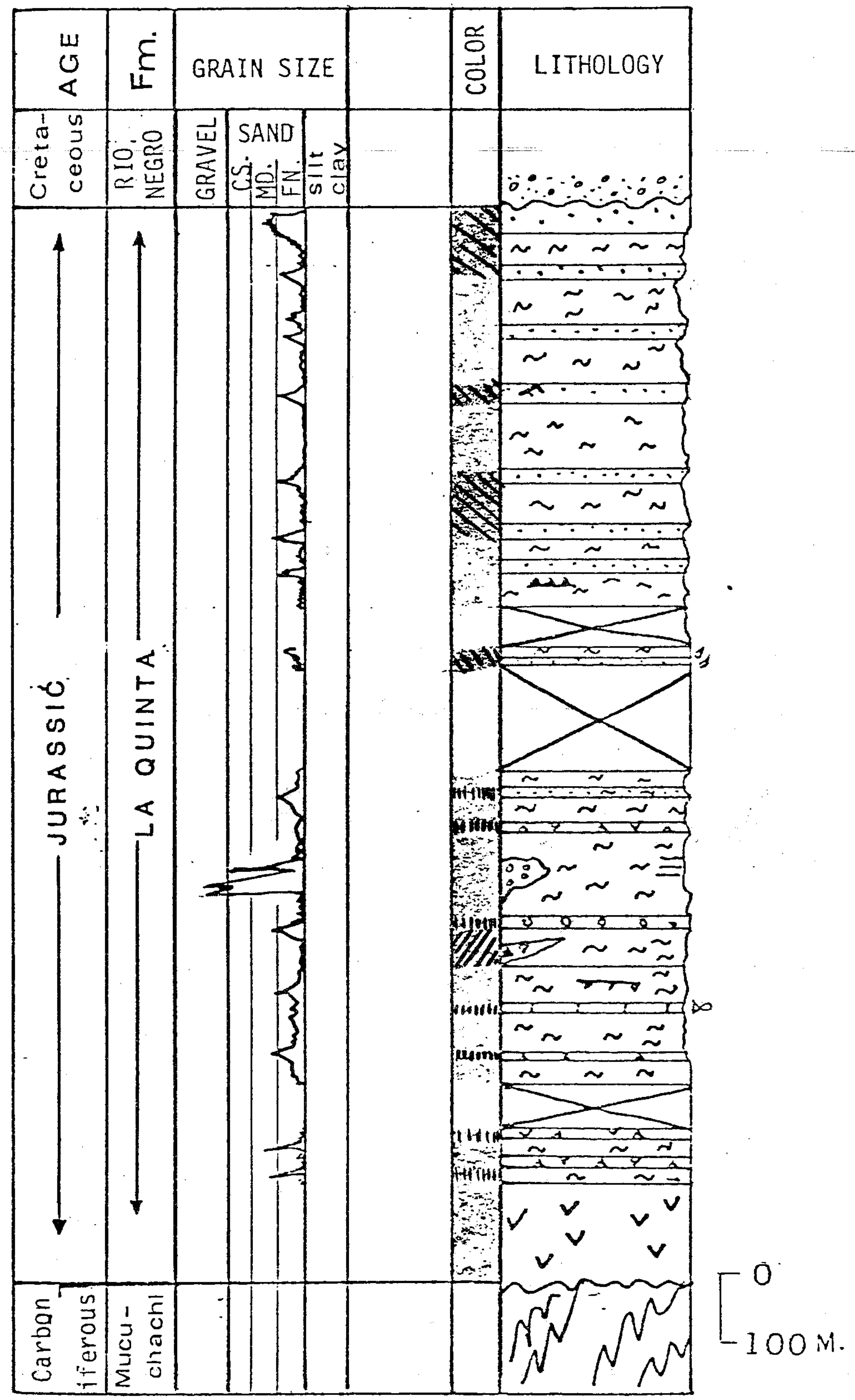
This section is well-exposed throughout all of its 1,610 m thickness. The bottom of this section (Figure 9) is characterized by 160 m of tuffs overlain by a 800 m thick unit of interstratified siltstone, sandstone, tuff, conglomerate and limestone. In this unit, some siltstone beds show mudcracks, parallel lamination and raindrop imprints (Figure 10). The tuff is present as beds or lenses (Figure 11); the sandstones mostly medium or coarse-grained, show gray and whitish colors and contain a great amount of tuffaceous material. The limestone restricted to this part of the section contains poorly preserved ostracods and fish remains. The uppermost 650 m of the section is made up of siltstone with ripples 20 to 30 cm in wavelength and 2 cm amplitude, and dark brown cross-laminated fine-grained sandstone characterized by a lack of volcanic-ash.

The tuffs of the lower part of this section (Figure 9), characterized by purple, gray, green, whitish, and pinkish colors and based on the content (over 60%) of glass, crystals, or rock-fragments were classified by Padron (1978) as vitric, cristal-rich tuffs and lithic tuffs. The tuff beds show thicknesses ranging from 50 cm to 14 m and exhibit a variable grain

Figure 9

LA QUINTA TYPE SECTION

(NO.3)



After Padron, 1978

Figure 10. Raindrop imprints found on the top of a bed of the La Quinta type section approximately 900 m above the base.

Figure 11. Lower interval of the La Quinta Formation at the type section looking north. Areas outlined are tuffaceous sandstone channels.

size between fine ash and lapilli, averaging coarse ash (1.7 to 1.9 m).

In general, the main mineral present in the tuffs is quartz which shows two different provenances, namely volcanic and metamorphic. Plagioclase is mostly altered to sericite or calcite. Some of it also shows albite and Carlsbad twins. Potassium-feldspar, chlorite, magnetite, zircon, biotite, muscovite, and rock fragments, which may be of either volcanic or metamorphic origin, also occur in the tuffs.

The dark brown siltstone beds common throughout the section have thicknesses of 10 cm to 4 m. They generally contain abundant matrix which consists of a mixture of sericite, chlorite, and hematite. The cement generally is calcite. The grains vary from angular to subangular and the sorting is variable from moderate to well sorted, and the silt is generally coarse-grained. Mineralogically, quartz is the predominant mineral and shows weak to moderate undulose extinction with some grains coated by hematite. The plagioclase follows the quartz in abundance and is commonly altered to sericite. Among the accessory minerals, biotite, leucoxene, epidote, zircon, sphene, tourmaline and rock fragments are the most common. Another common mineral is muscovite. This rock type, in the lower interval, is characterized by green and purple colors.

The sandstones are regularly distributed throughout the section, with the only difference being in the tuffaceous aspect of the sandstones located in the lower 800 m of the section and the non-tuffaceous aspect of the sandstones located in the upper 650 m. The former are gray and whitish, whereas the latter are characteristically dark brown. Toward the bottom of this section, they are mainly coarse-to medium-grained, whereas in the upper part, are mostly fine-grained. Based on Padron's petrographic study, the sandstones were classified as arkosic sandstone, feldspathic graywacke, lithic sandstone, and lithic graywackes. Arkose is characterized by low content of matrix and abundant quartz and feldspar; it is texturally immature with grains between angular and subrounded and sorting between poorly to well sorted. The feldspathic graywackes have abundant matrix, consists of a mixture of argillaceous material with sericite and chlorite. The red-colored sandstones also contain hematite, is calcite-cemented, is moderate to well-sorted in the fine-grained beds and poorly sorted in the medium-grained beds. Grains are angular to subangular and texturally immature. The arkose is characterized by its low content of matrix and cement, high content of

quartz, and relatively high content of plagioclase, with angular and subangular grains and moderate to poor sorting. The lithic sandstones are characterized by high content of rock fragments and textural immaturity. Finally, the lithic graywacke is characterized by its high matrix content which consists of a mixture of clay and chlorite; they are texturally immature.

Mineralogically, quartz (of volcanic and metamorphic provenance), plagioclase (in general altered to sericite or calcite), rock fragments (of volcanic, sedimentary, and metamorphic composition) and muscovite are the common. Among the accessory minerals are epidote, chlorite, and sphene. Others identified were hematite, magnetite, leucoxene and biotite. Padron pointed out that almost all the coarse-grained sandstones have variable amounts of volcanic material; therefore, he called them "tuffaceous".

<u>La Pulida Section (No. 4)</u>

This section is 1,390 m thick, but the lower part of the sequence is in fault contact with younger rocks (Figure 12). In general, from bottom to top, three units are recognized. The bottom of this section consists of a red and greenish-colored siltstone-dominated 800 m thick unit. The grain sizes of the sandstones within this siltstone units are medium to fine-grained. The latter becomes more abundant toward the top of the unit. The common structures and associated lithologies are small channels filled with medium-grained sandstones and parallel lamination in the fine-grained sediments. Convolute structures were observed in fine-grained sandstone overlain by trough cross-stratified sandstones.

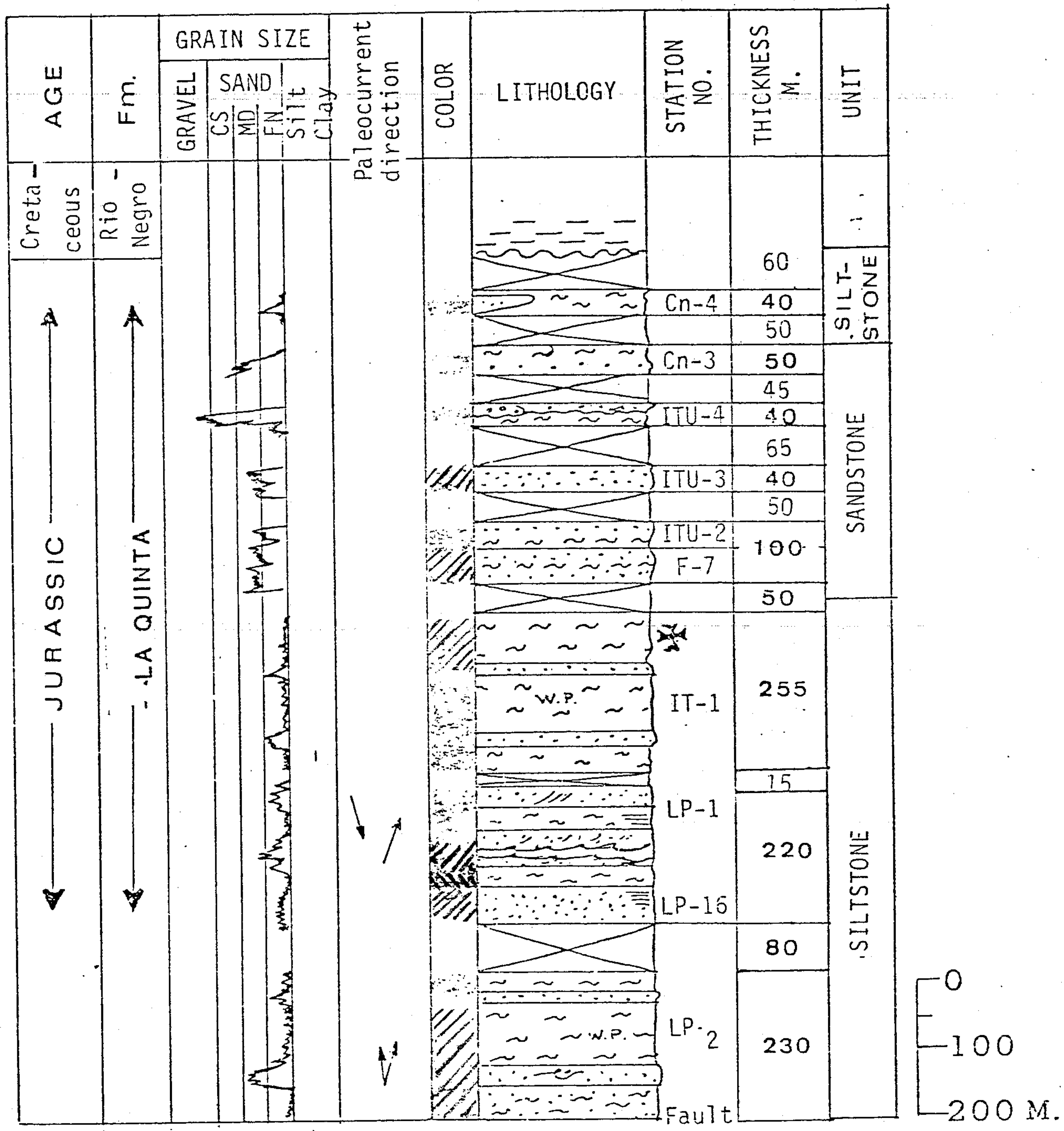
The siltstone-dominated unit is overlain by a sandstone-dominated unit 430 m thick. In this unit, sandstones represent 87% of the sediments and are mainly medium- to coarse-grained, showing different structure types and colors. Among the structures are tabular beds and scour and fill structures in sandstone units internally cross-laminated. Upward in this section some lenses of conglomerate occur and the grain size of the sandstones increases. The fine-grained sandstones as well as some siltstone beds have parallel laminations. The red siltstones contain greenish or white patches.

At the top of this section, there is a siltstone unit 160 m thick. In this unit it was not possible to observe any structures in detail because of the poorly preserved outcrops. Red and gray or greenish colors are interbedded throughout the section.

Figure 12

LA PULIDA SECTION

(NO.4)



The siltstone bed thicknesses vary from 0.9 m to a maximum of 25 m, averaging 3 m. In regard to the sandstone, bed thicknesses range from a minimum of 0.9 m to a maximum of 10 m, averaging 2 m. The thick sandstones are made up of scour fill sandstone units. Texturally, the sandstones at the bottom are submature arkose, whereas upward they are immature arkoses.

Mineralogically, in siltstones and sandstones quartz is the most abundant mineral followed by feldspar (plagioclase) and micas (muscovite, biotite and chlorite). Quartz shows some vacuole inclusions and undulose extinction. Feldspar mostly as plagioclase (and hard to differentiate from potassium feldspar), shows alteration to sericite and/or calcite. Occasional albite twins occur. Among the opaque minerals also present in this section are leucoxene, ilmenite, hematite, and pyrite (Appendix A). The common clay is illite, even though kaolinite and montomorillonite are present in small amounts (Appendix B).

Based on the directional structures (cross-stratification) of sandstones of this section an easterly paleoccurent direction ranging from N20E to S20E, was determined (Appendix C).

San Buenas Section (No. 5)

The La Quinta sedimentary sequence in the San Buenas area, located 20 km to the northeast of the La Pulida section (Figure 2), is faulted; therefore, no single complete section is exposed in this area.

The stratigraphic section at this area consists of thick lenses of sandstone separated by greater thicknesses of siltstones or shales (Figure 13). Even though this is only partial stratigraphic section, the measured thickness is 1,485 m.

The whole section (Figure 13), from bottom to top, is characterized by thick sandstone units, sometime made up of individual sandstone lenses, interstratifed in shales for the lower and upper portion of the section and interstratifed in siltstones for the middle portion of the section. Also distributed in the section are single sandstone lenses in flood basin deposits. The grain sizes of the sandstones are fine- or medium-grained, less commonly coarse-grained. Commonly the fine-grained sediments such as shales, siltstones, or fine-grained sandstones are red (light, dark or purple), less commonly greenish; whereas the medium- and coarse-grained sandstones are greenish or white.

At the bottom, the lowermost 290 m, the structures and associated lithologies are parallel lamination in some fine-grained sandstone strata, white or greenish patches in the structureless red shale beds, and convolute, deformational structures in the very fine-grained sediments. In the middle part of the section, some of the siltstone beds are ripple marked; load casts are also present at the bottom of sandstones overlying siltstone beds. Other structures include tabular cross-stratification in the sandstones. Overlying this segment the uppermost 242 m of the section is characterized by scour fill sandstones internally trough and tabular cross-stratifed which appear as thick single lenses interestratified in siltstone.

Some of the sandstone units of the section (SBr-8 and SBr-5, Figure 13) are made up of several sandstone beds which are separated by partings of shale laminae. The grain size for the SBr-8 sandstone unit is fine-grained; whereas the SBr-5 sandstone unit is medium- to coarse-grained (Figure 14). Some of the cross-stratified sandstone contain small amounts of organic matter at their bases (Figure 15).

The sandstone beds, as well as the sandstones of lenticular shape, show variable thicknesses from a minimum of 0.4 m to a maximum of up to 15 m. The thick sandstones are made up of sandstone lenses with variable thicknesses of 0.1 m to approximately 1 m.

The main minerals in the samples analyzed of this section were, in order of abundance: quartz, plagioclase, micas, opaque minerals and epidote, zircon and calcite. Quartz may be present up to 50% with mica, epidote and zircon inclusions. Some other quartz shows undulose extinction or mosaic structure. Plagioclase may be present, altered to calcite or to sericite; albite twins are present in up to 35% of the feldspar grains. The micas include muscovite and pleocroic chlorite. The chlorite pleochroism varies from colorless to very light green. The opaque minerals include ilmenite, leucoxene and hematite. The clay minerals identified by X-ray are illite as most abundant, and kaolinite and montmorillonite in very small amounts. The amount of matrix and cement in the sandstones is small. In the siltstone, the matrix is made up of a mixture of hematite, calcite and sericite. Texturally, the sandstones are classified as arkose and subarkose. They are moderate to well sorted and grains are angular in micas to subangular in quartz and plagioclases.

The directional structures of some sandstones of this section indicate a paleotransport direction ranging from

Figure 13

SAN BUENAS SECTION

(NO.5)

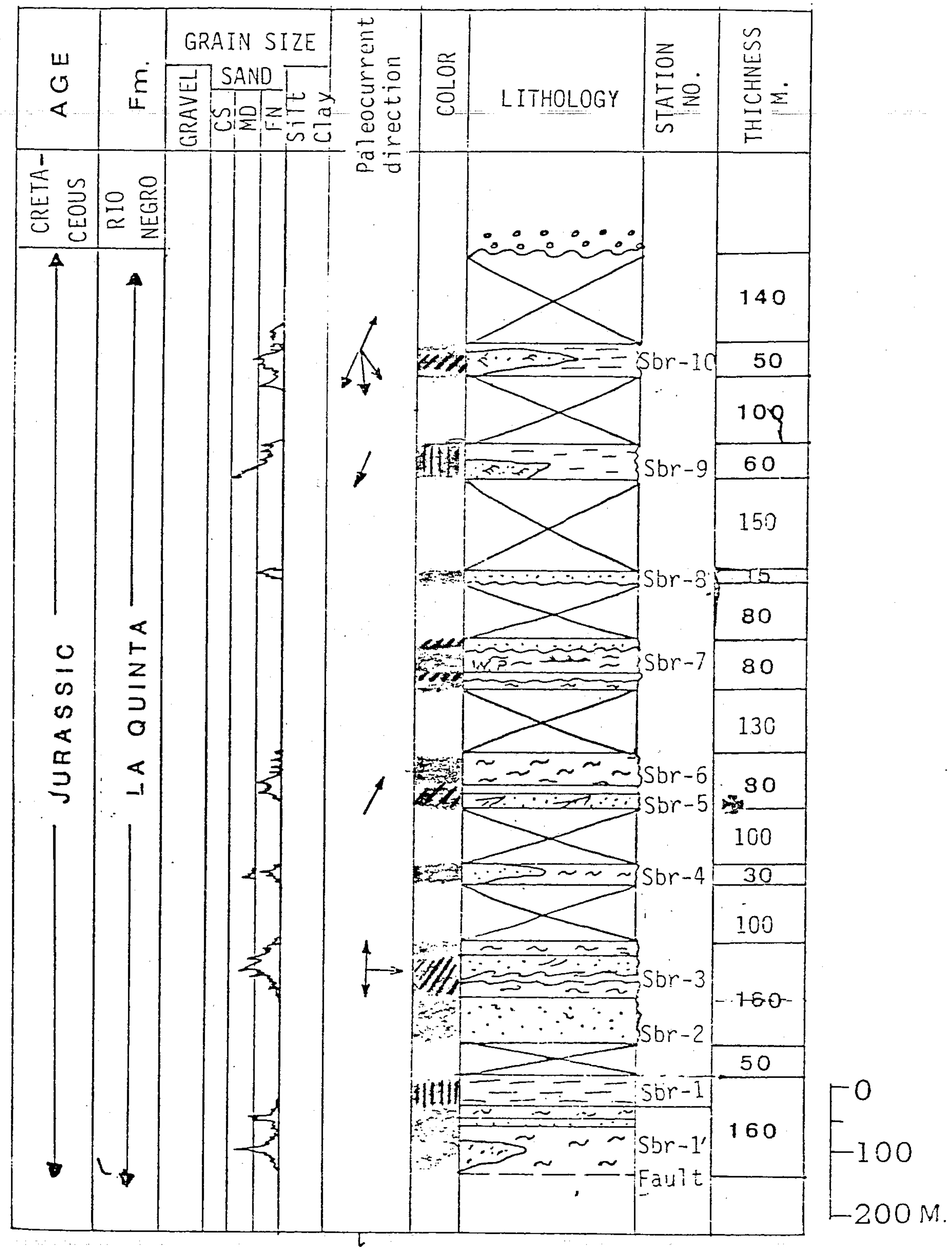


Figure 14. Carbonaceous, pyritiferous sandstone (San Buenas section outcrop SBr-5).

Figure 15. Close-up of the sandstone shown in Fig. 14, bottom of sandstone body where a radiometric anomaly was detected in the San Buenas section.

north to south for the lower 600 m, whereas the upper most part shows southerly paleocurrent directions ranging from S35E to S25W.

Pregonero Section (No. 6)

The Pregonero section (Plate 1) was originally described by Useche and Fierro (1972) and later by Perez (1977). This section was included as part of this study to facilitate interpretations of depositional environments.

The Pregonero section, at least 2,400 m thick, is located near the town of Pregonero, Tachira (Plate 1). Perez (1977) divided the section into three intervals. The lower interval, 400-600 m thick, consists of red conglomerate containing subrounded, boulder-size clasts of black phyllite, quartz, red sandstone and green meta-sandstone in red, sandy matrix. The middle interval, 1,000-1,200 m thick, consists of interstratified red and green fine-grained sandstone, silty sandstone, siltstone, shale and minor amounts of conglomeratic sandstone. The green units were noted to contain pyrite as a common accessory mineral. The upper unit, 1,200 m thick, consists of interbedded red and green siltstone, shale, limestone and sandstone. The sandstone units of this interval exhibit mudcracks. Limestone units of this interval are approximately 30 cm thick and are fossiliferous.

Color

The principal material which gives color to the red sediments of the La Quinta Formation is hematite. In the thin sections studied by this author, as well as others, it has been observed that this mineral is present as alteration product of iron-bearing minerals such as magnetite, ilmenite and biotite. Hematite occurs as microcrystalline agglomerates associated with the matrix, as grain coatings, and as cementing material.

Age

Traditionally, due to the almost total lack of fossils, the age of the La Quinta Formation had been uncertain and considered by many workers to be of Triassic-early Jurassic (Comisiõn Venezolana de Estratigrafía y Terminología, 1970). However, the plant remains found by Benedetto (Perez, 1977) in the La Quinta type section, Tachira, and in the State of Trujillo, the palynomorphs found by Padron (1978) in the type section, and the ostracods described by Perez (1977)

from the limestones of the La Quinta Formation in the Pregonero area indicate a range in age for the sediments of the La Quinta from the late Triassic to the early Cretaceous. Padron (1978) and Perez (1977) have concluded, therefore, that the La Quinta Formation represents deposition during most of Jurassic time.

Correlation

The extreme lateral variation in thickness and the lack of continuous outcrops, fossils, marker beds or any characteristic correlatable lithologies make difficult any accurate correlation in the continental sediments of the La Quinta Formation. In spite of this, the top of the La Quinta Formation for each of the five analyzed sections can be used as a datum horizon for correlation purposes (Plate 4). The reasons for assuming the top to be an approximate time surface are given below.

1. As considered by many workers, such as Gonzalez de Juana (1951) the La Quinta sediments were uplifted and underwent erosion at the end of the Jurassic. The end of this erosional period, which produced a relatively low relief topography in all of western Venezuela is recorded by a regional unconformity.

2. Even though the base of the stratigraphic sections of the La Quinta Formation is also an unconformity (Plate 4), it cannot be used as effectively as a datum horizon for correlation purposes because the stratigraphic study of the La Quinta sediments indicates a high relief topography at the beginning of the Jurassic. Even if the bottoms were correlatable, not all of the five studied sections have exposures of their bases. Therefore, their correlation would be questionable at best.

As shown in Plate 4, in the study area, the author has divided the La Quinta sequence into two informal intervals, upper and lower. The bases for such a subdivision are variable from one to another section and they are:

1. The abrupt variability in thickness in the studied sections over short distances i.e., between the San Juan de Colon (1,270 m) and the Angaraveca-El Zumbador sections (3,500 m).

2. The variations in paleocurrent directions displayed between the lower and upper intervals of the Angaraveca-El Zumbador and the San Buenas sections.

3. The difference in grain size of the sandstones of the lower and upper intervals in the La Pulida Section which increase upward as well as the sudden appearance of conglomeratic lenses interestratified with the sandstone of the upper interval.

4. The absence of volcanic debris in the uppermost 620 m of the La Quinta type section.

As will be explained later on, it is important to note both the fact that not all of the sections of the La Quinta Formation show the lower and the upper interval and that not all of the thin stratigraphic sections of the La Quinta Formation necessarily represent the upper interval.

The bases for making these intervals correlatable among each of the five studied stratigraphic sections are:

1. Stratigraphic relationship of the units shown on Plate 4.

2. The whole 1,270 m of the San Juan de Colon section display similar paleocurrent directions of transport that the upper interval of the Angaraveca-El Zumbador section; therefore, it is considered correlatable with the upper interval of the Angaraveca-El Zumbador section.

3. The presence of volcanic debris in the lower interval can be considered as deposited by currents flowing from the north-northwest (Figure 16) where the volcanic focus are supposed to be (Padron, 1978). This assumption is supported by some paleocurrent components of the lower interval of the Angaraveca-El Zumbador section. Therefore, this interval for both sections should be correlatable. The lack of volcanic materials upward in the La Quinta type section could be due to a change in source area during the depositional time of this interval. This is also indicated by the change in paleocurrent directions which took place between the lower and upper interval of the Angaraveca-El Zumbador section (Figure 16).

4. The presence of some similar paleocurrent components in the lower interval of the Angaraveca-El Zumbador and the La Pulida sections indicate the same transport directions for this interval in these two sections, therefore, this interval could be considered as having been deposited at the same times.

5. The average in paleocurrent directions of the lower interval of the La Pulida section can be considered as

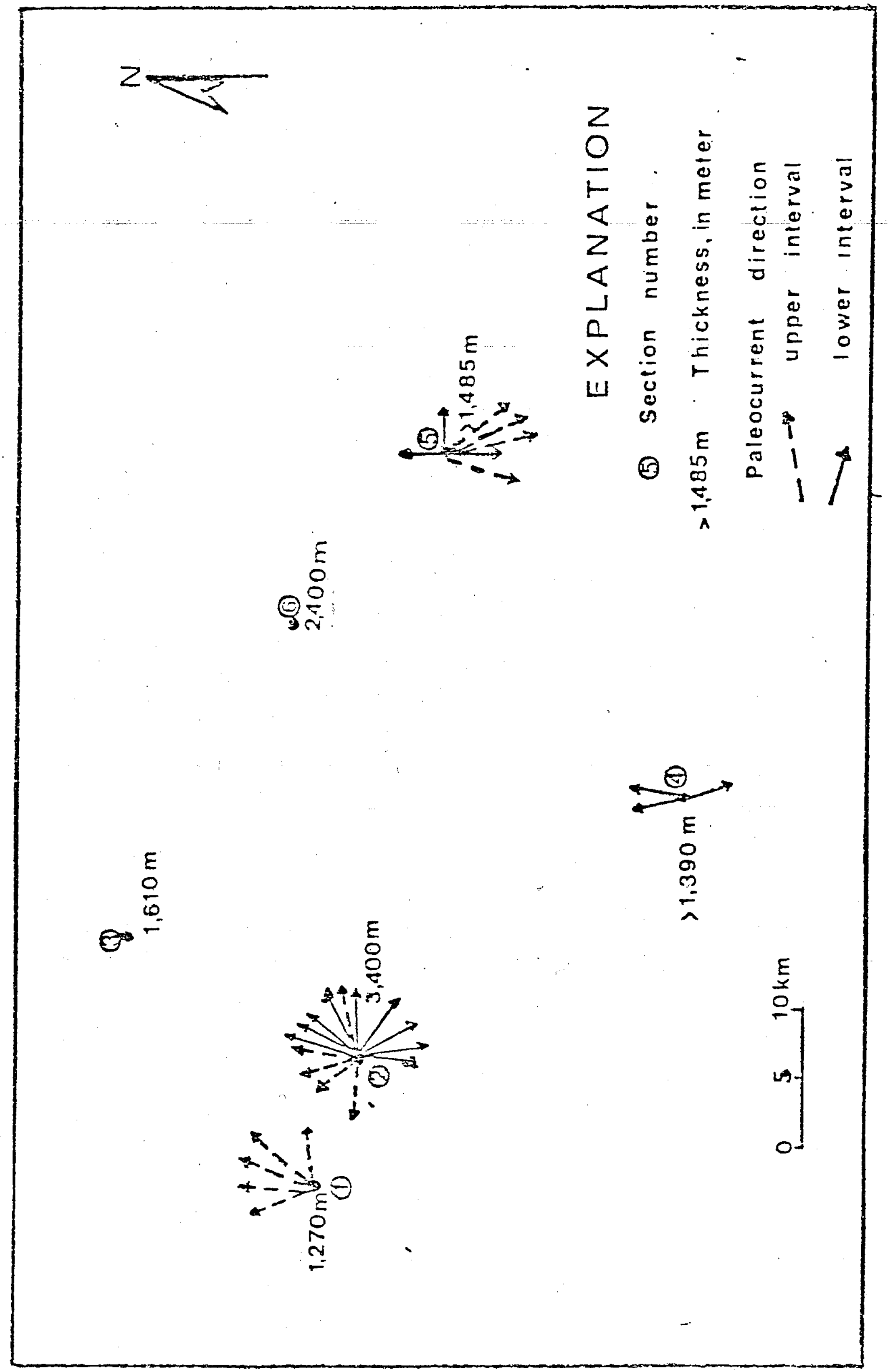


Figure 16 Paleocurrent directions and thicknesses of the La Quinta Fm. in the study area

similar to the average of the transport direction displayed by the sediments of the lower interval of the San Buenas section.

6. The upward change in paleocurrent direction in the San Buenas section indicates that some sort of tectonic event took place during the deposition of this interval. This is also recorded by the increase in grain size of the sandstone of the uppermost 550 m of the La Pulida section.

Depositional Environments and Paleogeography

General Statement

In this section, the environmental interpretations of previous workers and the author's proposed depositional environmental reconstructions are based on the lithologic assemblages, geometry of sandstone bodies, the type of sedimentary structures, and the grain size characteristics. Even though continuous outcrops of the La Quinta Formation are generally obscured, field evidence, together with the stratigraphic analysis, indicates that this sequence of rocks, in general, was deposited in a continental environment.

Environment Interpretations

The La Quinta Formation has been described by many workers, such as Sutton (1946) and Rivero (1956) (cited in Useche and Fierro, 1972) as having been of fluvial origin with sporadic marine invasion. This marine origin has been proposed because of the presence of calcereous intervals (limestones) in some sections such as the La Quinta type section and the Pregonero section. However, Padron (1978) and Perez (1977) in their work described the ostracods found in the limestones as being fresh-water species.

In the study area, the Jurassic sediments are dominated by terrigenous deposits consisting of conglomerates, sandstones, iltstones and shales with local limestones. In general, the measured sections are characterized by medium- to fine-grained sandstones. Based on the high feldspar content and on the angularity and poor sorting of the conglomerates and sandstones of the studied sections, these were classified as immature or submature arkoses.

The La Quinta sedimentary rocks in the studied area were divided into two informal intervals (Plate 4). Description of their distinctive lithologies and associated depositional environment in each of the five measured sections are given below.

La Quinta Formation: Lower Interval

Based on the results of this study, the author considers that the entire 1,270 m thick of the San Juan de Colon section (Figure 5) represents only the upper interval. Therefore, sediments which should represent the lower interval were probably not deposited in this area.

The lower interval in the Angaraveca-El Zumbador section (Figure 7) is 1,783 m thick and consists of a lower unit of current-bedded conglomerate interbedded with arkosic sandstone. The presence of conglomerates suggests that deposition occurred in longitudinal channel bars of braided streams in an alluvial fan (Ore, 1964). This unit is overlain by 400 m of fine- to medium-grained sandstones and siltstones, the latter being the major lithology. The cross-stratified sandstones occur as lenses in the siltstones. This unit seems to represent cut and fill by streams on a flood plain. The grain-size change in these sediments represents a prevalent environment of low energy with periods of sudden high water discharge. The top of this interval is made up of fine-grained, trough, cross-stratified sandstones. The range exhibited by the paleocurrent directions in this interval varies from N35E to E and from E to S25W averaging due east (Figure 16).

The lower interval in the La Quinta type section consists of 150 m of structureless tuff, overlain by 800 m principally of siltstones, with some tuffaceous sandstones, lenses of tuffs and conglomerates, and fossiliferous limestones. The characteristic features of this interval are structures such as parallel laminations, raindrop imprints, and mudcracks in the siltstone beds, as well as tuffaceous and conglomeratic lenses included in the siltstones. Plant and fish remains, as well as ostracods, are also present in this unit. Also characteristic of this interval is the abundance of tuffaceous material interbedded with the sediments. This unit seems to represent a flood plain cut by streams and with local ponding of the drainage. The floodplain environment is suggested by the abundance of siltstone. The presence of interbedded sandstones in the flood-plain siltstone results from lateral channel accretion. "The raindrop imprints and mudcracks constitute the best indicators of intermittent subaerial exposure of a sedimentation surface (Reineck and Singh, 1975)."

In order to explain the presence of limestones in some sections of the La Quinta Formation, the writer considers the possibility of ponding of drainage by several processes. Among them is the theory proposed by Padron (1978) that disorganization of normal drainage was due to tuffaceous debris which choked the streams. The author considers that such a process was not widespread throughout the area, since in the Pregonero region, another area where the existence of limestone is known, there is no volcanic evidence. Therefore, a possible explanation applicable to this area is ponding by warping of the basin. Another possibility is the presence of low relief areas adjacent to the Pregonero and La Quinta regions which were subject to high seasonal runoff. This runoff would have produced inundation of the flood plain, leaving ponds once the streams returned to their original stream channels. The presence of the tuffaceous channel near the top of the interval (Figure 11) can be explained by increased volcanic activity which produced the accumulation of large quantities of easily erodable pyroclastic debris. The precipitation runoff would have then quickly become choked with sediments and the stream would have begun depositing the material as channel fill.

The lower interval of the La Pulida section (Figure 12 and Plate 1) is made up of 790 m of mostly siltstone interbedded with thin beds of sandstones. Red and gray colors are interstratified throughout this interval. The structures observed included parallel laminations in some siltstone beds, convolute structures in the fine-grained sandstones, as well as trough cross-stratified sandstones. The grain size of the sandstone beds present in this interval is mostly fine-grained. This interval is similar to the lower interval of the La Quinta type section, with the exception of the finer grain size in this section and the absence of volcanic debris. Therefore, the depositional environment is assumed to be the same as that of the lower interval of the La Quinta type section, except for the absence of ponding at La Pulida. The general fineness of the water-laid sediments of the La Pulida section could indicate that the energy of the transporting streams was too low to transport gravel. The directional features of this interval indicate an average in paleocurrent direction of N10E (Figure 16).

The lower interval of the San Buenas section, 790 m thick, is characterized by red or gray siltstones and shales, even though sandstones are also present as tabular beds and lenses. The siltstones show parallel laminations and the sandstones display mainly cross-stratification, although in some fine-grained sandstones convolute structures were observed. This interval can be distinguished from the La Pulida section and the La Quinta type section because the siltstone and shale beds are thicker, because of the presence of thick dark gray shale beds which do not occur in the other two sections, and because the bottom of the sandstone lenses contain small amounts of organic matter. The paleocurrent directions displayed by the directional features of the sandstones of this interval indicate a variable easterly current direction (figure 16) from north to south with a probable average due east. In general, the previously mentioned lithology is common throughout the entire San Buenas section. Therefore, the environmental interpretation will be explained in the description of the upper interval.

La Quinta Formation: Upper Interval

The entire 1,270 m thickness of the San Juan de Colon section including the eroded uppermost 350 m (Figure 5), represents the upper interval. This interval mainly consists of red, fine-grained sediments, although sparse red conglomerate lenses are interbedded in the section. The very fine-grained sandstones show parallel laminations and the scour-fill medium-grained sandstones are internally cross-stratified. The directional features of these sandstones indicate an average in paleocurrent direction of N43E. The lithology and associated sedimentary structures suggest a depositional environment consisting of braided streams characterized by fine-grained sediments. Based on the grain size and paleocurrent directions (Figure 16), the author believes that coarser sediments were not available to the streams.

The upper interval of the Angaraveca-El Zumbador section begins with a medium-grained (689 m thick) sandstone unit. Some sandstones of the Angaraveca-El Zumbador section are wedge-shaped and represent the external expression of transverse bars (Ore, 1964), whereas other cross-stratified sandstones represent channel deposits. The fine-grained parallel-laminated sandstones represent channel-fill or overbank deposits. The characteristic structures are load casts; parallel laminations; tabular or trough cross-stratified sandstones; and scour features produced by small channels. The top of this interval is composed of red siltstones and shales which contain pseudonodules (Figure 6). This lithology represents flood-plain deposits. The average in paleocurrent directions for this interval is N5W (Figure 16).

The upper interval of the La Quinta type section consists of siltstones and fine- to medium-grained sandstones, the former being the predominant rock type. The only structures described by Padron (1978) were symmetrical, small ripple marks in the siltstones and cross-lamination in the sandstones, although he did not measure any paleocurrent directions. The finest sediment should represent a flood plain deposit. Lateral accretion of the streams is represented by the cross-stratified sandstones.

The upper interval of the La Pulida section consists of a lower unit 405 m thick of fine- to medium-grained sandstones interbedded with thin siltstone beds. Because the cross-bedded sandstones were inaccessible or badly weathered, no paleocurrent directions were measured. Sparse conglomerate lenses are also present in this interval and the top is made up of siltstones.

The upper interval of the San Buenas section is made up of the same lithology as the lower interval, with the only difference being the absence of abundant shale bed at the bottom of the section and the change in the paleocurrent direction from east, for the lower interval, to S15W, for the upper interval. The common structures in this interval are ripple marks, lenses of cross-stratified sandstones, and load-cast structures at the bottom of sandstones overlying siltstones. Also noticeable is the presence of small amounts of organic matter at the bottom of the sandstone lenses (Figure 15) and its absence in the other sections. Although almost the entire section is characterized by sandstone beds overlain by thick flood basin deposits, distributed in the section are some thick sandstone units (Figure 14) made up of lenses of fine- to medium-grained sandstone, separated by thin beds of carbonaceous shale or siltstones and thin wedges of fine-grained sandstones within flood basin deposits. The presence of these fining upward sequences in this section may indicate sedimentation in low relief areas farther from the uplifted source areas in a meandering stream environment. Based on Walker (1979), the first two sequences previously described should represent meander loops abandoned by neck cut-off (for the former), which is characterized by a thick sequence of overbank deposits (vertical accretion), and meander loops abandoned by chute cut-off (for the latter), which is characterized by a thin sequence of overbank deposits. The thin wedges of sandstone into flood basin deposits may represent crevasse splay deposits.

In summary, the lithologic data (Table 1) of the San Juan de Colon section, Angaraveca-El Zumbador section, La Pulida section, Pregonero section, and the La Quinta type section denote cut and fill by streams on a flood plain, where the flood plain deposits are represented by the finest sediment, siltstone or shale and the channels by scour-fill sandstone internally cross-stratified (Figure 6). These

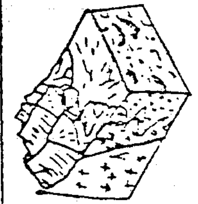
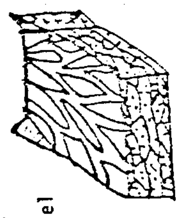
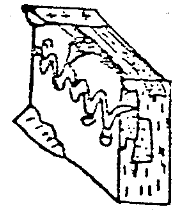
	DEPOSITIONAL ENVIRONMENT	PHYSIOGRAPHY	ENERGY	LITHOLOGY	COLOR	SEDIMENTARY STRUCTURES	BLOCK DIAGRAM SHOWING CONFIGURATION OF THE DEPOSITS
BRAIDED STREAMS	Upstream	Near mountain of gradient moderate	Fluctuating high to moderate	Poorly sorted pebbly conglomerates and sandstones	Red	Imbrication, trough cross-bedding	 modified from Bull, 1972
	Downstream	Far out in front of mountain ranges	Fluctuating long periods of low-water flow w/short periods of high-water flow	Fairly well sorted arkosic sandstones interbedded w/siltstones, rare shales and conglomerates	Red and Gray or Red	Scour and fill structures tabular and trough cross-stratification in sandstones, parallel lamination, mud cracks, convolute bedding, raindrop imprints, graded stratification & ripple marks	 After Allen, 1965
MEANDERING STREAMS	Meander loops abondoned by chute cut-off	Subdued topographic relief*	Discharge: extended periods of low-water flow to flood stage of shorter duration*	Thick arkosic sandstone beds interbedded w/thin shale or siltstone beds	Gray and Red	Fining-upward sequence, lag deposits* trough cross-bedding & trough cross-lamination*, convolute bedding, white patches, ripple marks, load casts and scours, organic matter	 Explanation: Lateral accretion deposits; Conglomerate; Sandstone; Vertical accretion deposits; Shale or siltstone. Modified from Allen, 1965
	Meander loops abandoned by neck cut-off			Thin arkosic sandstone beds interbedded w/thick shale or siltstone beds			
	Crevasse splay			Single, thin tongues of sandstone into shale or siltstone			
	Ephemeral lakes	low relief	Fluctuating short periods of high w/long periods of low	Limestones and shales	Gray & red	Parallel lamination, fresh-water fossils, raindrop imprints & mudracks	

TABLE 1. Principal Depositional Environments Recognized in the La Quinta Fm. in the North-Central Part of Tachira, Venezuela

*Taken from Literature

types of lithologies and their sedimentary structures, together with the relative proximity to positive areas which were tectonically active, indicate the presence of a system of braided streams in these regions during the Jurassic. These braided streams are characterized by a moderate flow regime indicated by the presence of trough cross-stratified sandstone and a lower flow regime suggested by the parallel-laminated, fine-grained sediments (Reineck and Singh, 1975). Variations in sedimentation caused by flooding are represented by increasing or decreasing grain sizes, observable in the outcrops of the sections as well as from section to section. The presence of coarse sediments interbedded in the sections suggests a sporadic, recurrent high water discharge rather than a continuous flow regime. The presence of sandstone units made up of scour-fill sandstones internally cross-stratified (Figure 6) which are included in siltstones, suggests that the sandstones were deposited by high energy streams which rapidly switched depositional sites. As previously mentioned, the lithologies and the sedimentary structures displayed by the San Buenas section suggest that sedimentation took place in an area of low relief characterized by a meandering stream environment. The gray-colored sediments together with the presence of organic matter denotes sedimentation in a more strongly reducing environment in this area.

Lithofacies and Paleogeography

Figures 17 and 19 illustrate the paleocurrent directions and distribution of facies of the lower and upper intervals of the La Quinta Formation. Figures 18 and 20 show the interpreted paleogeography during the deposition of the two intervals in the study area.

The coarsest-grained facies and the sediment transport directions obtained by cross-bedding measurements in outcrops of the La Quinta Formation together with the presence of thick sequences, suggest that streams flowed off of uplifted blocks and deposited the coarsest material closest to the source area, that is at the Angaraveca-El Zumbador and Pregonero areas (Plate 1).

Figures 17 and 18 show the facies map, the paleocurrent directions, and the interpreted paleography for the lower interval of each section. The lower interval for the Angaraveca-El Zumbador section is mainly characterized by a high percentage of sandstones and conglomerates. The directional features of these lithologies indicate a widespread range of paleocurrent directions with a general trend eastward. The

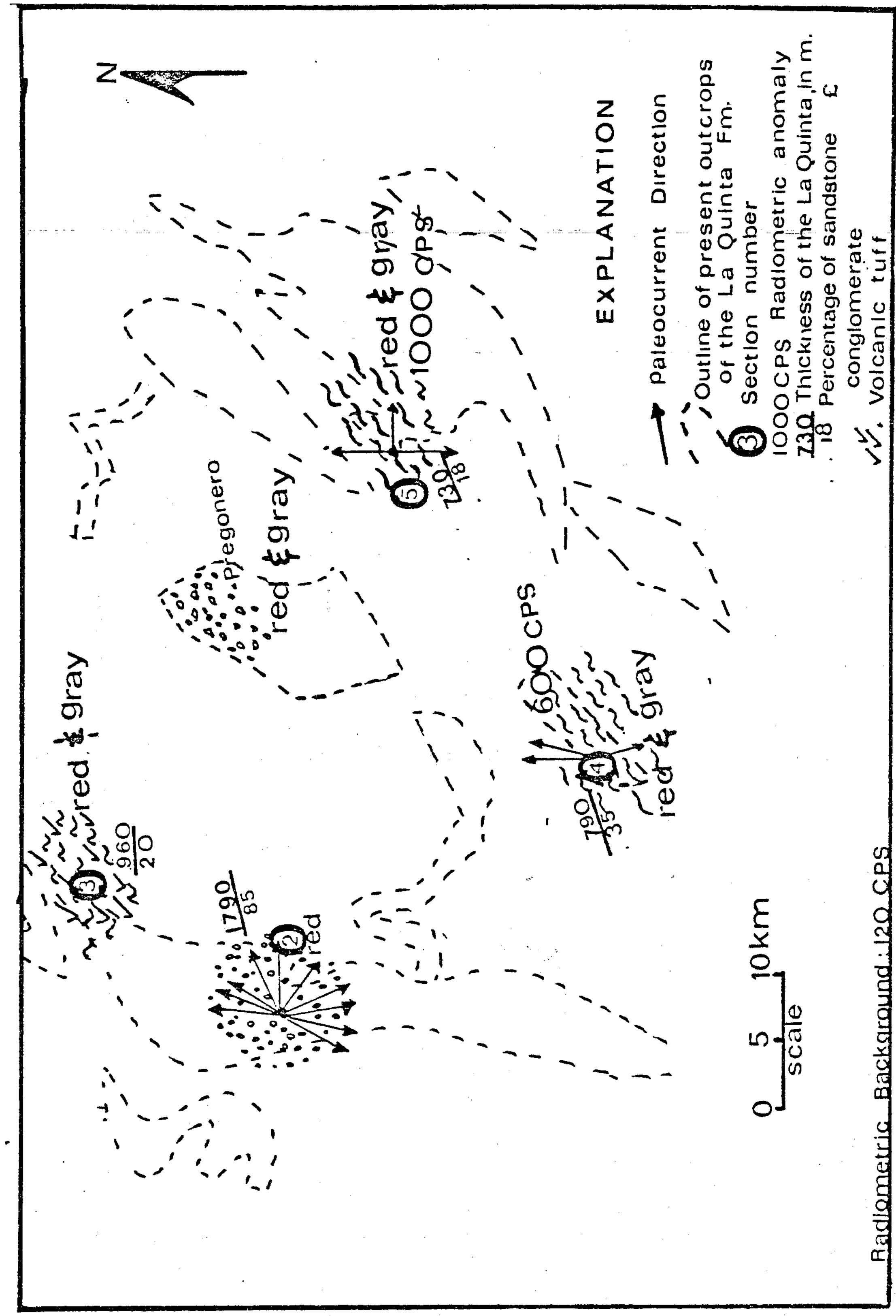


Figure 17 Facies Map - La Quinta Fm. Lower Interval

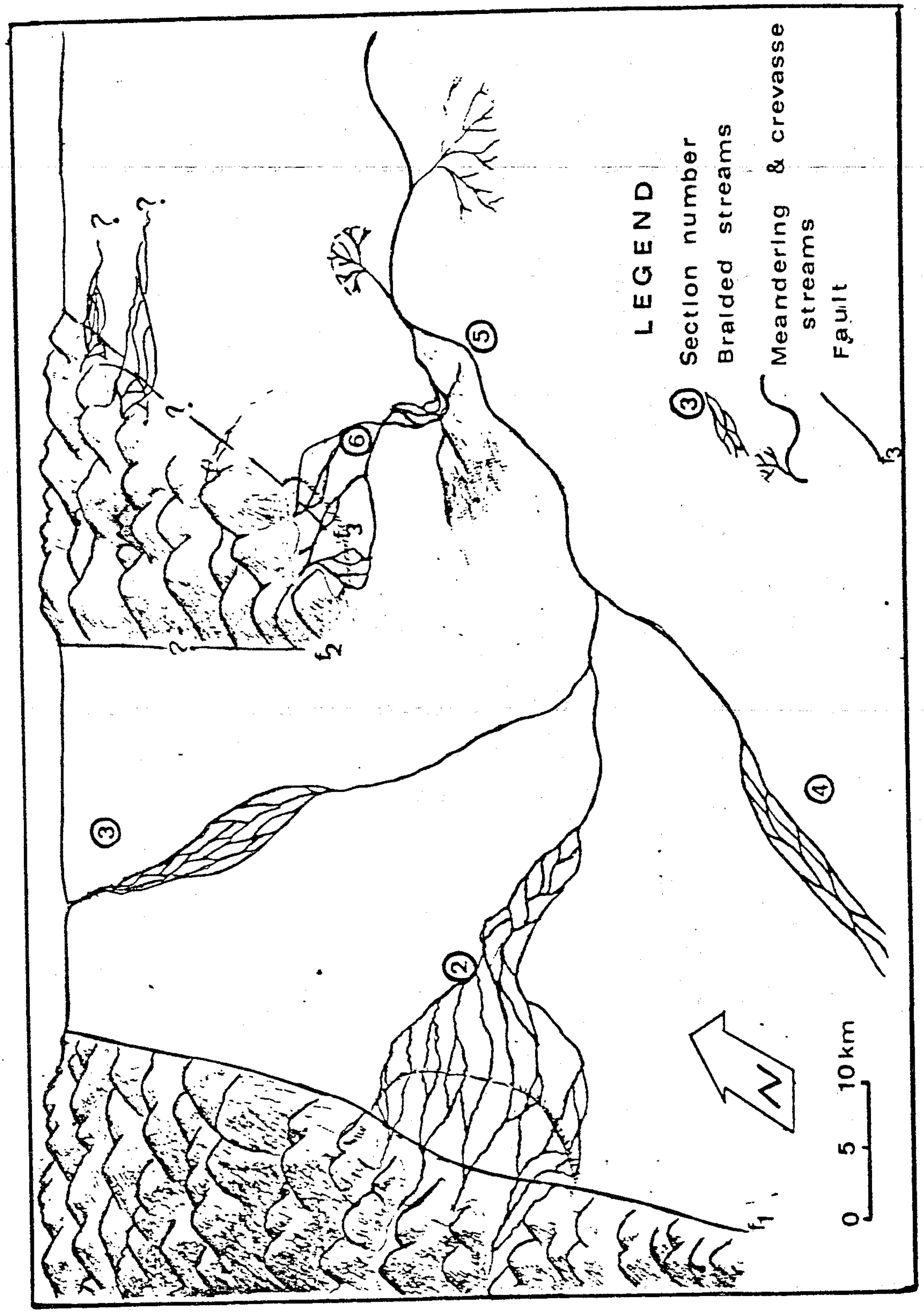


Figure 18 Interpreted Paleogeography of the lower Interval

La Quinta type section is characterized by a mainly siltstone-tuffaceous facies whereas the La Pulida section consists of fine-grained sandstone and siltstone, with an average in paleocurrent direction of N10E. The San Buenas section, made up of mainly siltstones and shales, shows a paleocurrent average to the east. Based on Perez's (1977) lithologic description, the lower part of the Pregonero section consists of sandstone and boulder conglomerates with minor amounts of siltstones and shales. From the data of this interval, together with the interpreted environemnt of deposition for the studied sections, the author considers that a braided stream system was present in the study area during the deposition of the lower interval represented by the lowermost sediments of the Angaraveca-El Zumbador section, the La Quinta type section, the La Pulida section and the Pregonera section. This system changed to a meandering channel facies toward the low relief area of the San Buenas section. The paleocurrent direction of each of the sections indicates source areas for this interval located to the west-northwest (Angaraveca-El Zumbador section), to the southwest (La Pulida section) and probably to the north-central part of the Pregonero section . All the data could be integrated in the paleogeography shown on Figure 18.

Figures 19 and 20 show the facies map, the paleocurrent directions and the interpreted paleogeography and paleoenvironments for the upper interval of each section. The San Juan de Colon section, located in the west portion of the area, is characterized by fine-grained sandstones with directional features that indicate an average of N43E. The Angaraveca-El Zumbador section is characterized by a sandy facies. The paleocurrent directions indicate a shift in the transport directions to the northeast. However, minor contributions from a highlands located to the west-central part of the study area could have occurred, as displayed by some paleocurrent components (Figure 16). The absence of volcanics in the upper interval of the La Quinta Formation can be explained on the basis of changes in the pattern of sediment transport directions that took place between the upper and lower intervals produced by tectonic activity. Based on the paleocurrent direction displayed by the lower interval of the Angaraveca-El Zumbador section the most likely is that sediment transport for the lower interval of the La Quinta type section was from the northwest, the assumed location of a volcanic center during the early Jurassic. During the deposition of the upper interval, the major sediment influx came from the southwest (Figures 19 and 20). Therefore, the disappearance of volcanic debris in the upper interval of the La Quinta type section can be attributed to changes in direction of paleocurrents, rather than to sudden cessation of volcanism , even

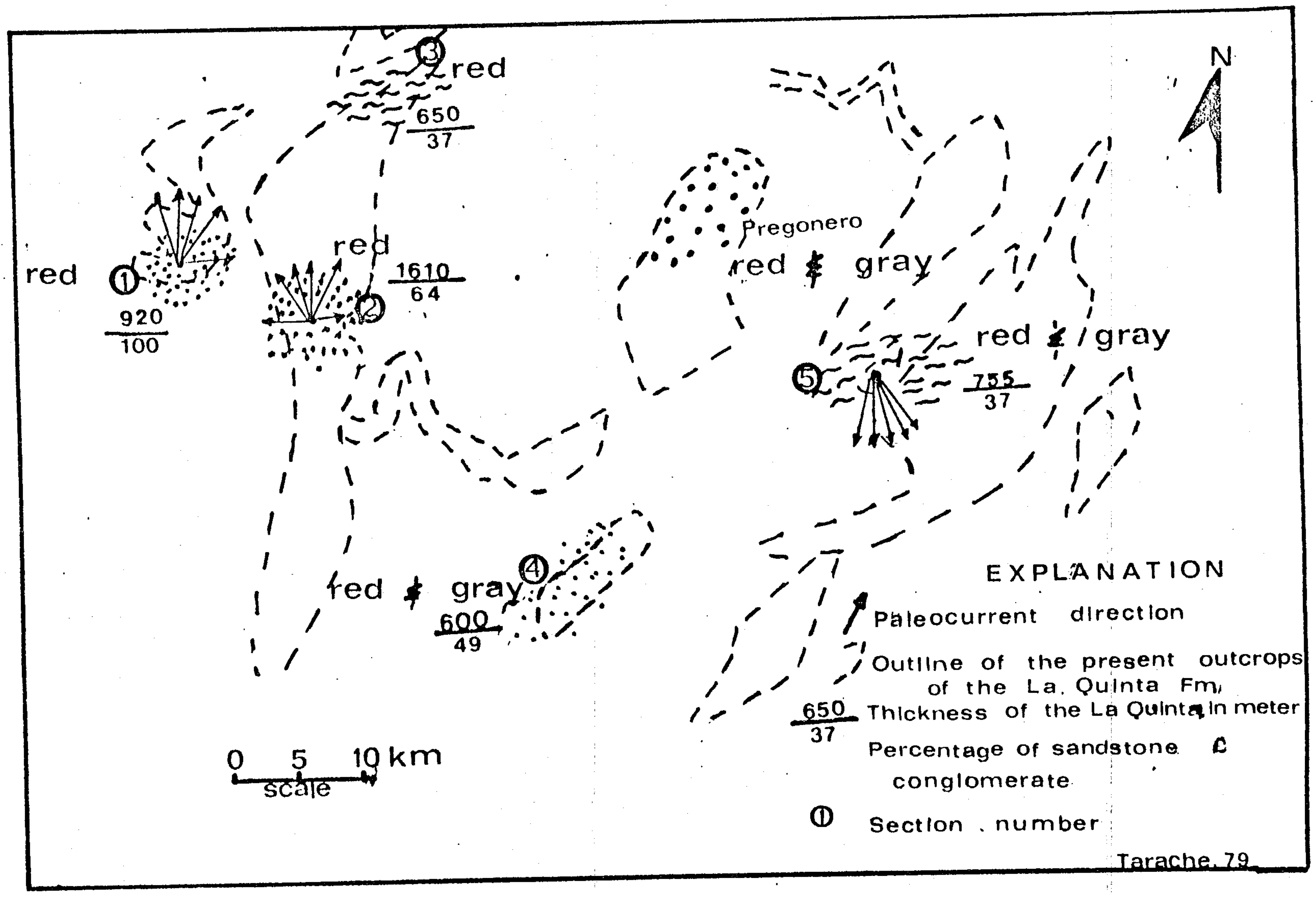


Figure 19 Facies Map - La Quinta Fm. Upper Interval

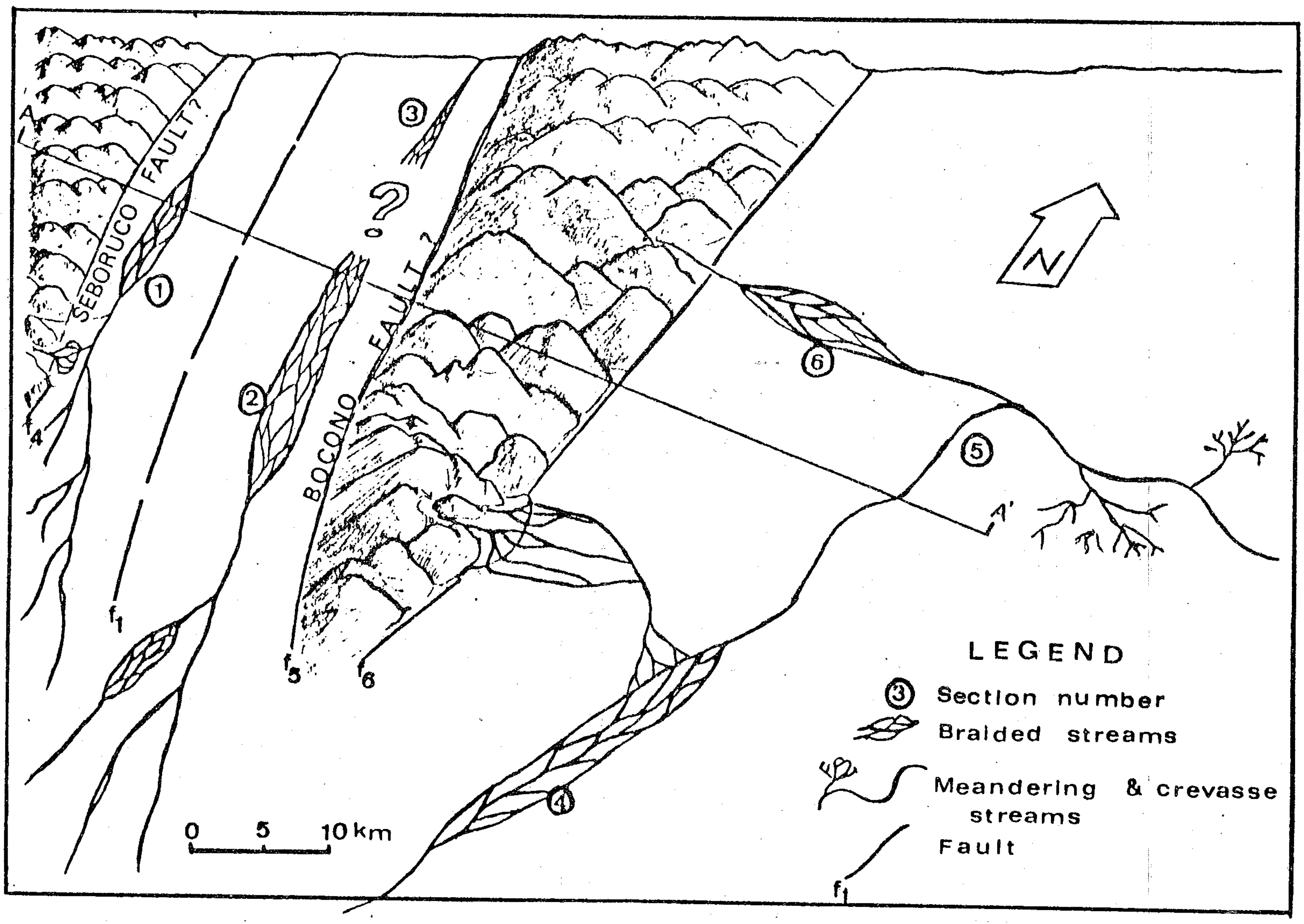


Figure 2o Interpreted Paleogeography of the upper Interval

though such a possibility can also be considered. The upward coarsening of the grain size shown for the La Pulida section, the change in paleocurrent direction showed by the directional features of the sandstones of the upper interval of the San Buenas and the Angaraveca-El Zumbador section, the absence of tuffaceous material in the uppermost 660 m of the La Quinta type section suggest that sedimentation during sometime in the Jurassic was affected by tectonism that produced the uplift of a west-central block and an "en echelon" fault system to the west of the area (Figure 20). The whole 1,270 m of the San Juan de Colon section was deposited in one of the troughs developed by this "en echelon" fault system, whereas other pre-existent troughs containing deposits of the lower interval were either receiving sediments or were uplifted and underwent erosion. This could explain the great variability in thickness displayed by this formation, even its absence in some parts of the study area (i.e., the central part of the study zone, Plate 1).

The whole San Juan de Colon section is considered to represent the upper interval because the paleocurrent direction displayed by the directional features of the sandstones is N43E, which matches with the paleocurrent direction of the upper interval of the Angaraveca-El Zumbador section.

Based on Shagam (1972), the whole sequence of the La Quinta sediments were deposited on horsts and grabens. At least in the central part of the study area, this type of structure seems to play an important role during the deposition of the upper interval (Figures 20 and 21), although it is possible that such structures produced the uplifting of the source areas at the margins of the study zone during the deposition of the lower interval.

In summary, the lithofacies and paleocurrent map of the lower interval (Figure 19) suggest that during the deposition of this interval, the uplifted areas were located in the Angaraveca-El Zumbador and Pregonero regions, whereas the rest of the area constituted a depositional basin (Figure 18) drained by rivers which came from the northwest, west and southwest depositing gravel and sand as braided stream deposits in alluvial fans in regions close to the source area (Angaraveca-El Zumbador and Pregonero regions) and depositing sand and siltstone as braided deposits farther from the source area (La Pulida section and La Quinta type section). Finally these streams graded to meandering streams in the low relief area of San Buenas. Therefore, the author considers that the lower interval of the La Quinta

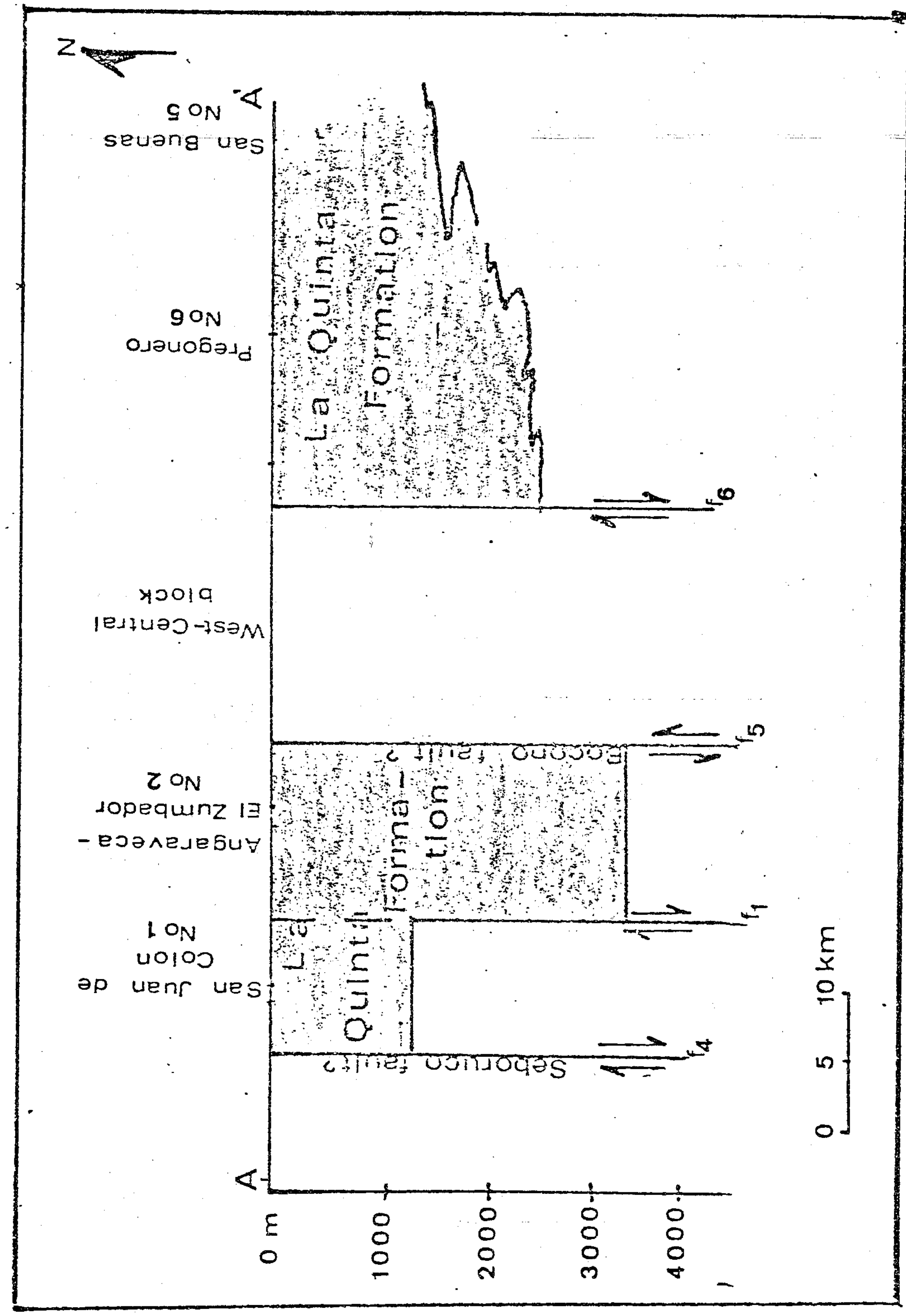


Figure 21: Structural framework during the deposition of the upper interval of the La Quinta Fm. (cross-section A-A' of figure 20)

Formation was deposited everywhere in the study area except in the highland located to the west and north-central portion of the study zone which probably were uplifted by faults (f_1, f_2 and f_3, Figure 18). The fault numbered 1 is underlain by cretaceous sediments (Plate 2).

The upward coarsening of the grain size shown for the La Pulida section, the upward change in paleocurrents displayed by the Angaraveca-El Zumbador and the San Buenas sections suggest that sometime during the Jurassic sedimentation was affected by tectonism which produced reactivation of old structures (fault 1) and the formation of new faults probably Seboruco (f_4), Bocono (f_5) and f_6. The Seboruco fault (f_4) and fault 1 formed an "en echelon" fault system whereas the remaining faults (f_5 and f_6) formed a west-central horst (Figure 20). This west-central block divided the area into two depositional basins where the deposition of the upper interval took place. The sediments of the lower interval of the La Quinta Formation which were located on the horst block underwent erosion. In this way, the absence or thinning of sections (Plate 1) of the La Quinta Formation could have been produced. In the grabens, the sedimentation was either continuous or began for the first time (i.e., at the San Juan de Colon Section). This tectonism also brought a change in the location of source areas.

On the basis of the analysis of the actual fault system of the area (Plate 1), the author believes that the absence of the La Quinta sedimentary rocks in some places can be explained as being simply unexposed due to the down-drop of these areas by post-depositional faulting rather than by selective sedimentation of the La Quinta Formation in different horst and grabens as suggested by many workers (e.g., Shagam, 1972) at least for the study area.

In spite of this interpretation, the author believes that other detailed work in the area and adjacent regions should be done in order to confirm or modify the present interpretation.

Sediment Source

The main sources of detritus for the La Quinta sediments were the Precambrian-paleozoic rocks exposed in nearby uplifted areas, Jurassic volcanic material and possibly sediments of the lower interval of the La Quinta sedimentary rocks.

The Precambrian and Paleozoic sources are indicated by the pebbles of granite, quartzite, phyllite, biotite schist and slate that occur in the conglomerates, as well as by the mineralogic composition of the analyzed samples and tuffs located at the lower part of the La Quinta type section.

The minerals identified through the microscope were quartz, which display either straight or undulose extinction and mineral or vacuole inclusions, micas (muscovite or biotite), and feldspars which are commonly plagioclase. This plagioclase alters to either calcite or sericite; therefore, it is possible that this plagioclase is calcic. This type of plagioclase is extremely unstable in sediments and commonly is an indicator of concurrent volcanic activity (Folk, 1974).

The previously mentioned quartz types seem to have a metamorphic origin, except for the quartz with mineral inclusions which are most likely of pegmatitic origin.

In regard to the sediments of the lower interval of the La Quinta Formation as a source of sediments, the author did not find any clear evidence of it. However, Perez (1977) in his mineralogic description of the conglomerate of the Pregonero section pointed out "sandstone" fragments.

Climate and Color

The presence of illite in the samples analyzed, the abundance of mica in sediments of some sections, the preservation of some sedimentary structures such as raindrop imprints and mudcracks, the red color of the sediments and absence of preserved plant debris, as well as the presence of braided-stream deposits, suggest an arid to semi-arid climate. In regard to the presence of raindrop imprints and mudcracks, Reineck and Singh (1975) state that these structures have better chances of preservation in areas receiving only occasional rain. They have been reported mainly on continental deposits in arid and semi-arid climates. In addition, the presence of the braided-stream channel deposition suggests high seasonal runoff. The abundance of mica in sediments of some sections may attest to the general inefficiency of chemical weathering in the source area and also suggests an arid climate.

Sediments in the analyzed stratigraphic sections represent channel and floodplain deposits, some of which accumulated on well-drained slopes favorable for oxidation and coincident destruction of any included organic material. Other sections, like La Pulida, San Buenas, and the La Quinta type section, show evidence of the presence of both oxidizing and reducing conditions, where the former is represented by reddish-colored sediments and the latter by grayish or greenish colors. The red color of the La Quinta sediments is due to hematite, which, as Walker (1967) has demonstrated in his study of Pleistocene red beds, comes from the alteration of iron-bearing minerals in terrigenous sediments by the action of oxidizing interstitial ground water. He also explains that there is a difference in color in the sequence due to a variation of the interestratal fluid in Eh and pH. In summary, based on Walker's hypothesis, the red color was developed <u>in situ</u> ; therefore, the red beds are not deposited with the red coloration. It is acquired later from diagenetic processes.

In contrast, Van Houten (1968) describes the pigment hematite as being created by transforming ferrous minerals to ferric minerals after a long weathering process in the source area that forms lateritic soils. Later these iron minerals in the ferric stage are eroded from the source and transported to the basin of deposition where these minerals give the red coloration to the sediments.

The author believes that Walker's red bed-forming model best fits the La Quinta situation because most of the factors pointed out by him, such as ilmenite partially altered to leucoxene, magnetite replaced by hematite, iron-bearing silicates altered to clay minerals, iron oxide, and calcium carbonate, were observed in the La Quinta sediments. Also, the difference in color in the same sequence cannot be explained as a change in source rock because the source was always the same during the Jurassic. Therefore, the red coloration of the La Quinta sediments was developed <u>in situ</u> .

ECONOMIC GEOLOGY

Geochemistry of Uranium

Uranium is a lithophile element and as such it is concentrated by processes active in the crust. Because uranium has a propensity to concentrate in silicic rocks and in sediments, it is widely distributed throughout granites, arkosic sediments, black shale, etc. De Voto (1978) pointed out that, "through magmatic differentiation, uranium is relatively concentrated in acidic and alkalic volcanic ashes, ash-flow tuffs, and volcanoclastics units." All these rocks have been suggested as possible sources of uranium for many deposits throughout the world. The estimated average uranium content of granite is between 3 and 5 ppm.

The migration and distribution of uranium during weathering and sedimentation is intimately connected with processes of oxidation and reduction. Therefore, it is important to know the chemistry of the groundwater because uranium is moved by groundwaters through rock of relatively high permeability until it is precipitated in a reducing environment. According to Best (1973), "the pH in natural groundwaters ranges from 5 to 9 and the Eh from +0.4 to -0.4; it also contains CO_2. Therefore, the uranium complexes usually found in these waters are UO_2OH^+, $UO_2(CO_3)_2\ 2H_2O^{-2}$, and uraninite, UO_2". Langmuir (1977) states "the uranium in natural waters is usually in the form of complexes; these complexes greatly increase the solubility of uranium and the mobility of uranium in surfaces and groundwaters".

Exploration for Uranium in the La Quinta Formation

This study is the first attempt to evaluate the uranium potential of the La Quinta Formation in Venezuela. The La Quinta Formation seems to have all the favorable conditions for uranium deposition. The arkosic rocks derived from metamorphic and granitic rocks were deposited in a continental environment by fluvial streams in a semi-arid climate. Volcanic ash is abundantly present in the La Quinta strata therefore, the La Quinta Formation has been proposed as a possible target for uranium exploration in Venezuela, even though abundant significant radioactive anomalies have not been found yet. However, in Colombia, rocks of the Giron Group, which have been correlated with the La Quinta Formation, display important radioactive anomalies.

Only two very local radiometric anomalies associated with sediments of the lower interval, were detected. One of these anomalies occur at the La Pulida section and another at the San Buenas section (Figure 16 and Plate 4). At the La Pulida section a small radiometric anomaly, 600 cps in a background of 120 cps (scintillometer exploranium, model GRF-101) occurs in gray fine-grained silty shale of the flood plain deposits (Figure 12). Associated with this anomaly is minor copper staining. The other anomaly, 1.000 cps in a background of 120 cps occurs at the San Buenas section in organic matter present at the bottom of the light gray or white, medium-grained, cross-stratified sandstone lenses of the meandering facies (Figure 13). No anomalies were detected in the areas where the sections of the Angaraveca-El Zumbador, the San Juan de Colon, or the La Quinta type sections are located.

Based on the facies maps obtained for the two intervals (Figures 17 and 19) and on the presence or absence of reductants, the best places to search for uranium occurrences include the facies change to finer sediments that occur between the La Pulida and the San Buenas sections, between the Pregonero and the San Buenas sections and between the Angaraveca-El Zumbador section and La Quinta type section. Not withstanding that the radiometric anomalies were detected at the lower interval, the author suggests to search the whole sections, located in the places previously mentioned. Unfortunately, much of the La Quinta Formation between the La Pulida and San Buenas sections is not exposed because it has been down-dropped as a result of faulting. Based on the presence of reductants in the San Buenas section and probably in the surrounding zones, within a radius of approximately 20 km these seem to be favorable target areas. As previously mentioned, organic matter and pyrite were both observed in the San Buenas section and only pyrite in the La Pulida section. The presence of pyrite and grayish or greenish colors in some of the analyzed sections (i.e., La Pulida) indicate reducing conditions with alternation of oxidation conditions such as those represented by the red beds present in the same sequence.

In regard to the possible uranium sources, the author suggests two possible sources: a granitic source for the southwestern sections and a granitic-volcanic source for the north-northwest sections. A volcanic source is suggested for the northern area because of the occurrences of tuffaceous sediments in this area. Even though condition of sedimentation and source are favorable for uranium to be deposited in the area between the Angaraveca-El Zumbador and La Quinta type sections, oxidation in this area is more intense. Therefore if uranium migrated and was deposited, such a deposit would be gone because of the destruction of the organic matter by oxidation in that area.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Several conclusions relative to the stratigraphy and tectonic events, as well as uranium occurrences, in the La Quinta Formation in north-central Tachira have been determined on the basis of a detailed analysis of five sections.

1. The La Quinta Formation in the study area shows a variable thickness ranging from 0 m to up to 3,400 m. Among the five sections, the thickness ranges from up to 1,200 m in the San Juan de Colon section to 3,400 m in the Angaraveca-El Zumbador section.

2. The Jurassic sedimentary rocks of the La Quinta Formation are dominated by detrital deposits consisting of red and gray conglomerates, immature or submature arkosic sandstones, siltstones, shales, and local limestones deposited in a continental environment by a fluvial system.

3. The San Juan de Colon section, the Angaraveca-El Zumbador section, the La Quinta type section, the La Pulida section, and the Pregonero section were deposited by braided streams, whereas the San Buenas section was deposited by meandering streams.

4. The main sources of detritus for the La Quinta sediments were: Precambrian and Paleozoic rocks exposed in nearby uplifted areas, Jurassic volcanic material, and probably sediment of the lower interval of the La Quinta Formation.

5. Based on the sedimentary characteristics displayed by the La Quinta Formation in the studied sections, two informal intervals, upper and lower, have been established for the formation in the study area.

6. The lower interval of the La Quinta Formation was deposited everywhere within the study area, except in the high-land areas located to the west and to the north-central portion of the study zone.

7. During the deposition of the lower interval, the whole study area constituted a large depositional basin drained by a fluvial system with a general transport direction to the east.

8. The changing sedimentary characteristics between the two intervals suggest the occurrence of a tectonic event that produced horsts, grabens, and an "en echelon" fault system in the area.

9. The time of deposition in the Jurassic of the lower and upper intervals, as well as the occurrence of the tectonic events, is uncertain. Presumably, faulting produced the uplifted blocks located at the west and north-central margins of the study area at the beginning of deposition of the lower interval.

10. Tectonic activity occurred after the deposition of the lower interval which produces a west-central block which divided the area into two main basins of deposition.

11. The upper interval of the La Quinta Formation was deposited in a structural framework of horsts and grabens, thereby restricting the areas of sedimentation to the troughs and the sediment source areas to the horsts.

12. An arid or semi-arid climatic condition for the depositional time of the La Quinta sediment is suggested by the presence of illite and the preservation of mudcracks and raindrop imprints, as well as by the presence of braided stream channel environments of deposition. This suggests that there may have been high seasonal runoff.

13. The red pigment of the La Quinta sediments is due to the hematite produced by alteration of the iron-bearing minerals *in situ*.

14. The presence of a meandering stream facies and of reductants in the San Buenas area make it a favorable target area for uranium exploration, as well as the surrounding area within a radius of approximately 20 km.

15. Two possible sources of uranium have been determined: volcanic and granitic detritus.

Recommendations

During the fieldwork, only two local radioactive anomalies were found by the author. The first one is associated with gray, cupriferous, silty shale in the La Pulida section, and the second one is associated with a whitish, carbonaceous, pyritiferous sandstone channel in the San Buenas section.

Future exploration for uranium deposits in the La Quinta sediments would be facilitated by recognition of the features mentioned previously in the subsurface or in outcrops. Therefore, the author (based on De Voto's paper 1977) would recommend, as a first stage in further exploration, that the following be done:

1. A detailed geologic map covering the different outcrop areas of this formation along with an alteration map.

2. A hydrogeochemical survey to understand the ground-water hydrology in the areas chosen as targets by the first step.

3. For this specific case, radon and helium soil-gas surveys may be helpful for selected sites.

4. A study of the chemistry of the pre-Mesozoic granitic bodies and of the Mesozoic volcanics to determine uranium content of these probable sources.

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APPENDIX A

SEDIMENTARY PETROLOGY

San Juan de Colon Section (No. 1)

Station No.	% Quartz	% Plagioclase	% Micas	% Opaque	% Matrix	% Cement	% Other	% Traces	Descriptions	Rock Name	Hand Specimens Descriptions
SJC-4	35	20	15	10		20			Opaque: leucoxene & ilmenite Cement: hematite angulars to subangulars Micas: muscovite silty, fine sandstone	"Arkose"	Dark brown, quartz-micaceous, fine-grained, slightly calcareous
LBC-3	55	28	10	7		10	Sericite		Cement: hematite Opaque: hematite Micas: muscovite & biotite, pleocroic golden to dark brown Plagioclase: altered to sericite & w/ albite twin	Brick red Oome rock Arkose	Quartz-feldespatic, micaceous and fragments, sandstone

Station No.	% Quartz	% Plagio-clase	% Micas	% Opaque	% Matrix	% Cement	% Other	% Traces	Descrip-tions	Rock Name	Hand Specimens Descriptions
LBC-5	15*								Groundmass: (clay = 85%) *grains silt size groundmass made up of hematite & sericite (?)	Silty Shale	Brick red, w/some conglm. fragments (calc. & feldspar) well cemented siltstone
OC-4	35	20		5	25	15	Chlorite		Cement: calcite, mosaic w/some inclusions, zircon, rutile & biotite Plagioclase: altered to sericite & calcite subrounded to rounded	Arkose	
	41*	25		8	20	5	1		Opaque: ilmenite altered to leucoxene, hematite & ilmenite without alterations Matrix: calcite & hematite Quartz: with ondulose extinction & mosaic type with mineral inclusions		Dark brown, calcareous cross-laminae, sandstone

Station No.	% Quartz	% Plagio-clase	% Micas	% Opaque	% Matrix	% Cement	% Other	% Traces	Descrip-tions	Rock Name	Hand Specimens Descriptions
OC-4	18	40		7	35	Calcite		Muscovite	Plagioclase: mostly altered to sericite or calcite - a few show albite carsbald twins Opaque: ilmenite & leucoxene Matrix: groundmass (hematite, calcite & sericite (?)). The angular or subangular grains are dispensed in the matrix, without touching between them	Arkose	Fine sandstone

Angaraveca - El Zumbador Section (No. 2)

Station No.	% Quartz	% Plagio-clase	% Micas	% Opaque	% Matrix	% Cement	% Other	% Traces	Descrip-tions	Rock Name	Hand Specimens Descriptions
									Quartz: w/inclusions of tiny crystals Plagioclase: albite twins Opaque: ilmenite leucoxene & hematite Micas: pleocroic: colorless to green	Siltstone	Reddish, x-laminae, porous, quartz-feldspatic, very fine-grained sandstone. Angular to subangular fragments

Station No.	% Quartz	% Plagio-clase	% Micas	% Opaque	% Matrix	% Cement	% Other	% Traces	Descrip-tions	Rock Name	Hand Specimens Descriptions
ANR-16	60	20		5		12		3	<u>Cement</u>: hematite <u>Opaque</u>: hematite <u>Cement</u>: hematite & calcite		Dark red, quartz-micaceous, slightly calcareous, very fine-grained sandstone
ANR-7	33	20	7	20		20			In some places the amount of cement decreases compared w/ another interials course siltstone or v. fine sandstone	"Arkose"	Subangular to subrounded grains
LAC-1	45	30	20				5	Muscovite	<u>Plagioclase</u>: altered to sericite <u>Quartz</u>: mosaic & composite <u>Opaque</u>: hematite	"Arkose"	Dark red, quartz-feldspatic, fine-grained sandstone w/some coarse calcareous & feldspatic fragments
									<u>Plagioclase</u>: some are sericitized		Dark red, fine-grained sandstone
PEG-1	45	13	20	7	Hot	18			<u>Cement</u>: hematite some fractures are filled with calcite	Coarse Siltstone "Arkose"	

Station No.	% Quartz	% Plagio-clase	% Micas	% Opaque	% Matrix	% Cement	% Other	% Traces	Descrip-tions	Rock Name	Hand Specimens Descriptions
					La Pulida Section (No. 4)						
LP-6	45	25	3	7		20		Zircon	<u>Cement</u>: calcite <u>Micas</u>: muscovite, chlorite (pleocroic colorless to dark green) <u>Opaque</u>: hematite, ilmenite & leucoxene <u>Plagioclase</u>: some grains are altered to sericite & some w/ albite twin angulars to rounded v. fine sandstone	"Arkose"	Light red, quartz-feldspathic - micaceous, well-cemented, porous, fine-grained sandstone calcareous
LP-8(I)	55		30	15					cross-laminae <u>Mica</u>: muscv., biot. & chlorite <u>Opaque</u>: leucoxene & pyrite (abundant) muscovite, groundmass = matrix	Coarse grained siltstone	Gray, quartzose-micaceous, well cemented, porous, calc. v. fine-grained ss
									<u>Plagioclase</u>: altered to sericite	Sandy Siltstone	
									<u>Micas</u>: angulars	Arkose	

Station No.	% Quartz	% Plagio-clase	% Micas	% Opaque	% Matrix	% Cement	% Other	% Traces	Descrip-tions	Rock Name	Hand Specimens Descriptions
T-7	15	10	33		35				<u>Quartz & Plagioclase</u>: subangulars Opaque: pyrite Siltstone or v. fine ss Quartz: show inclusions (like vacuoles) Opaque: leucoxene, ilmenite & hematite Cement: hematite v. small amount of matrix Plagioclase & feldspar - the former show albite	"Arkose"	Dark red, mica-fedspar-quartz, well-cemented, fine-grained sandstone Microscopic Description: twins & also are altered to sericite and calcite. Clorite-biolite (pleocroic colorless to either light brown or light green)
LP-8	35	25	30	7 Leucoxene			3 Chlorite		Shale or very fine siltstone	"Arkose"	light gray (greenish), well-cemented slightly calc., quartz, fine-grained siltstone

Station No.	% Quartz	% Plagio-clase	% Micas	% Opaque	% Matrix	% Cement	% Other	% Traces	Descrip-tions	Rock Name	Hand Specimens Descriptions
				San Buenas Section (No. 5)							
10								Zicron	Not cement, not matrix Opaque: leucoxene		White, quartzose - feldspatic, coarse-grained sandstone
SBR-5	55	35	8	2					Quartz: w/ mica inclusions & also mosaic texture, medium to coarse grains (mostly medium) Mica: musev. & sericite Matrix: made up by calcite, hematite & sericite (?) Matrix is coated by hematite	"Arkose" **Sandy Siltstone**	
AC-2	15	7	25	1	52			Chlorite	Plagioclase: some fragments altered to calcite & others show albite twin	Arkosic Wacke	Dark brown, calc., micaceous-quartzose siltstone

Station No.	% Quartz	% Plagio-clase	% Micas	% Opaque	% Matrix	% Cement	% Other	% Traces	Descrip-tions	Rock Name	Hand Specimens Descriptions
AC-5	56	15	22	7				Calcite, zircon & epidote	Matrix: small amount = clayley Opaque: hematite & leucoxene Plagioclase: mainly altered to sericite & calcite Quartz: overgrowth w/ mineral inclusions (epidote (?) & zircon (?)) Micas: muscovite sericite	Subarkose	White, fine-grained sandstone

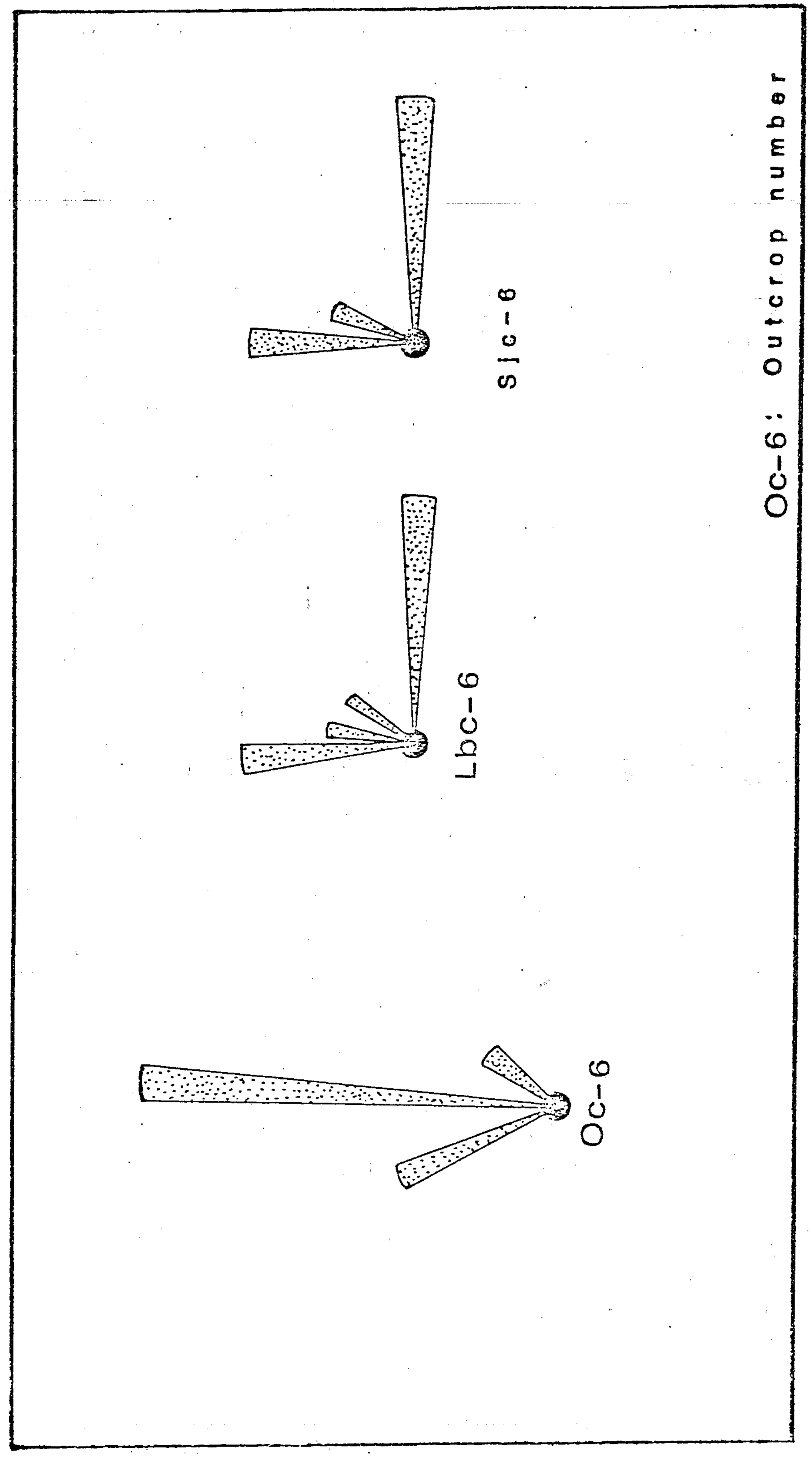
APPENDIX B

Clay Minerals

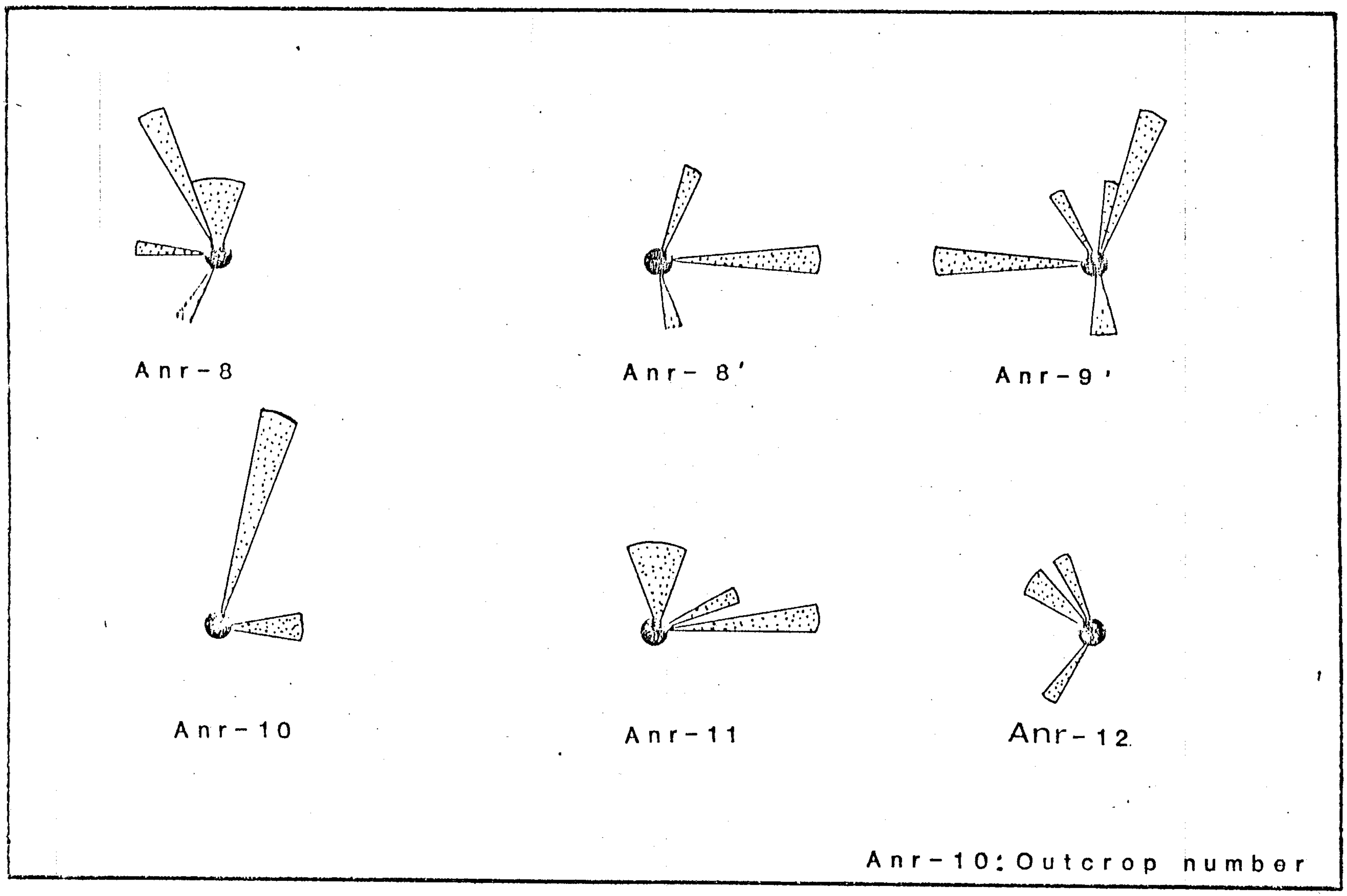
Sample Number	Clay Types
San Juan de Colon Section (No. 1)	
OC-6	kaolinite (small amount)
Angaraveca-El Zumbador Section (No. 2)	
Anr-13	kaolinite
Anr-14	illite, kaolinite and montmorillonite (small amount)
La Pulida Section (No. 4)	
T-7	illite
rlf-4(x)	illite
San Buenas Section (No. 5)	
AC-3	illite and kaolinite
SBr-2'	illite

APPENDIX C

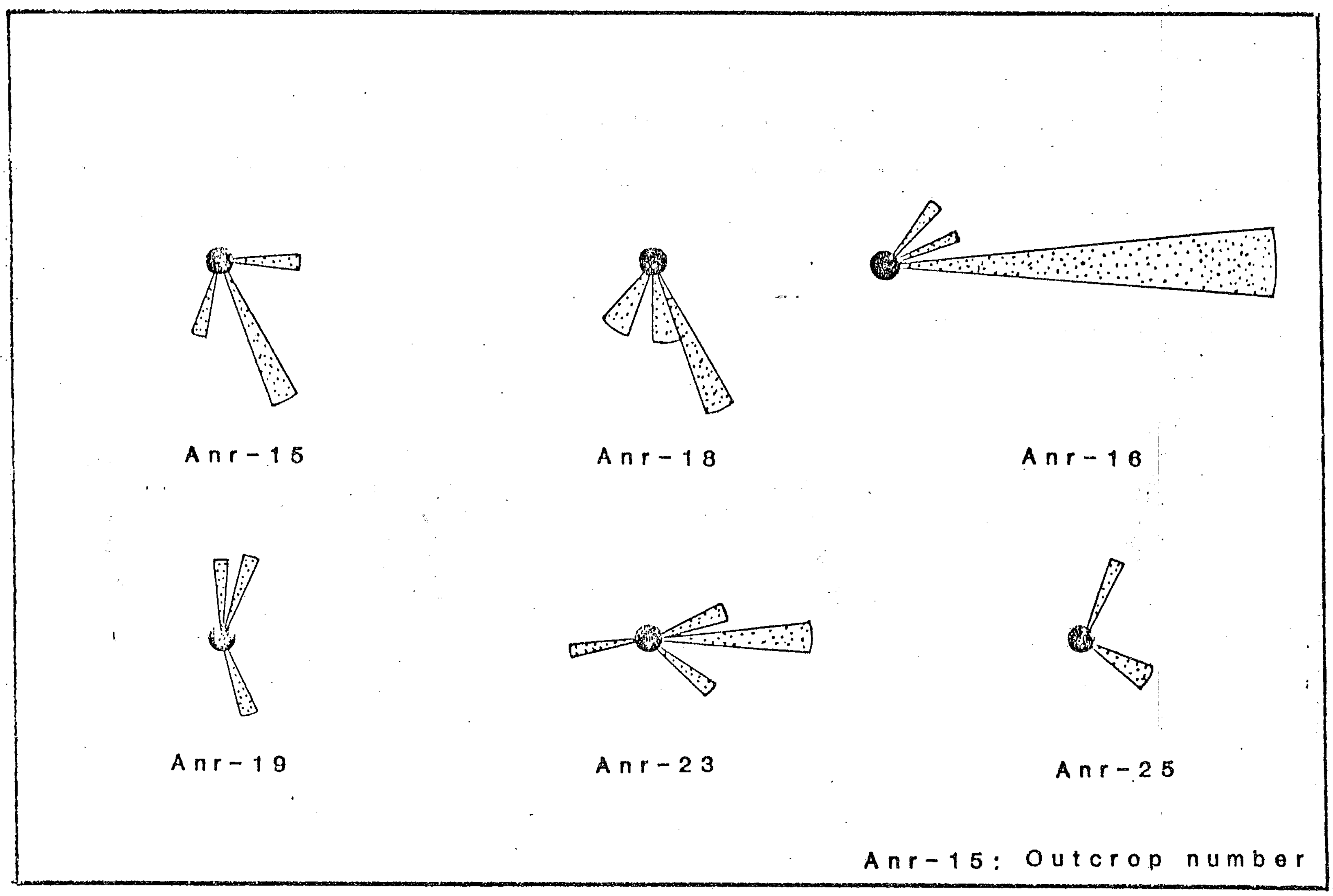
CURRENT ROSES



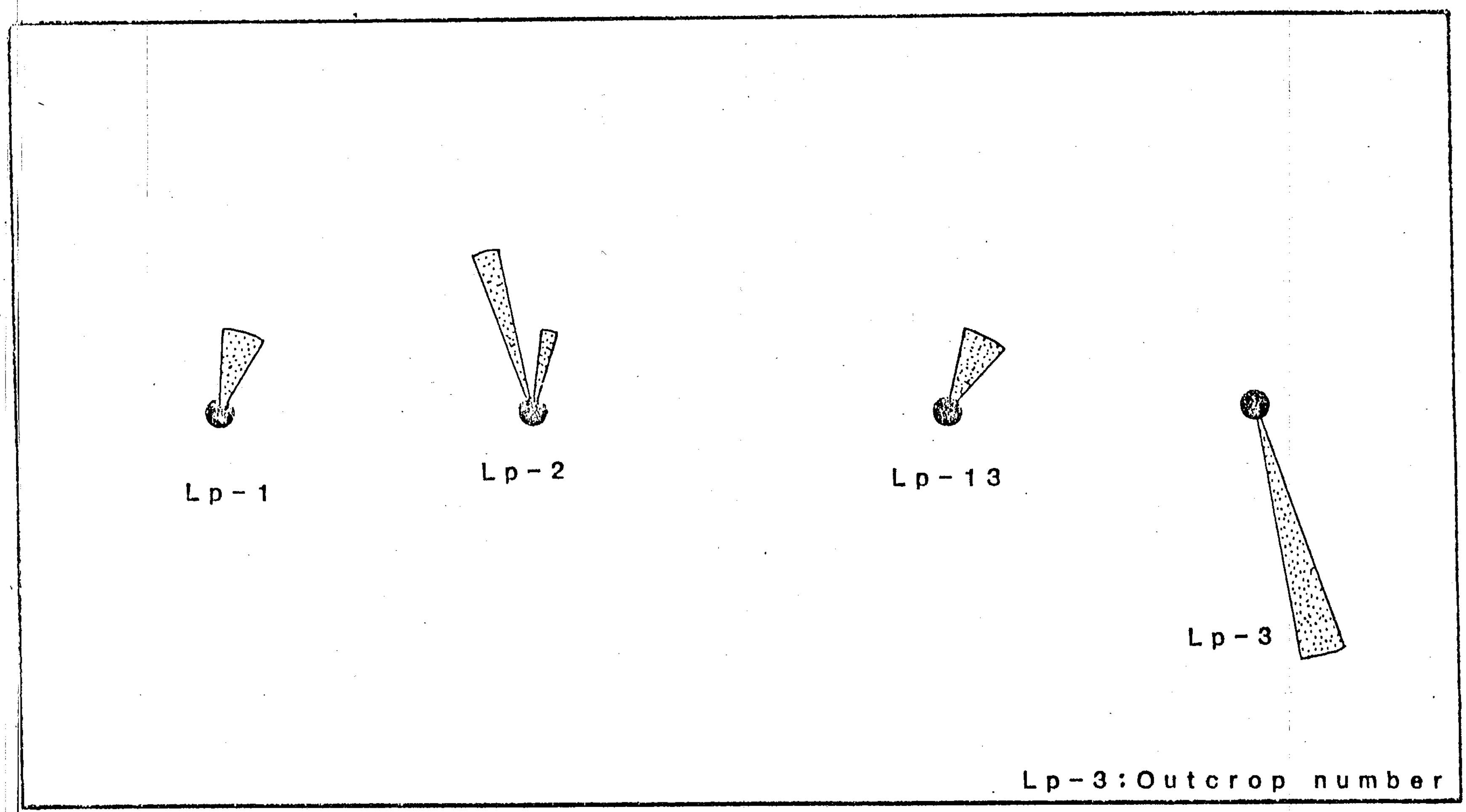
Current roses of the cross-stratification in the San Juan de Colon section



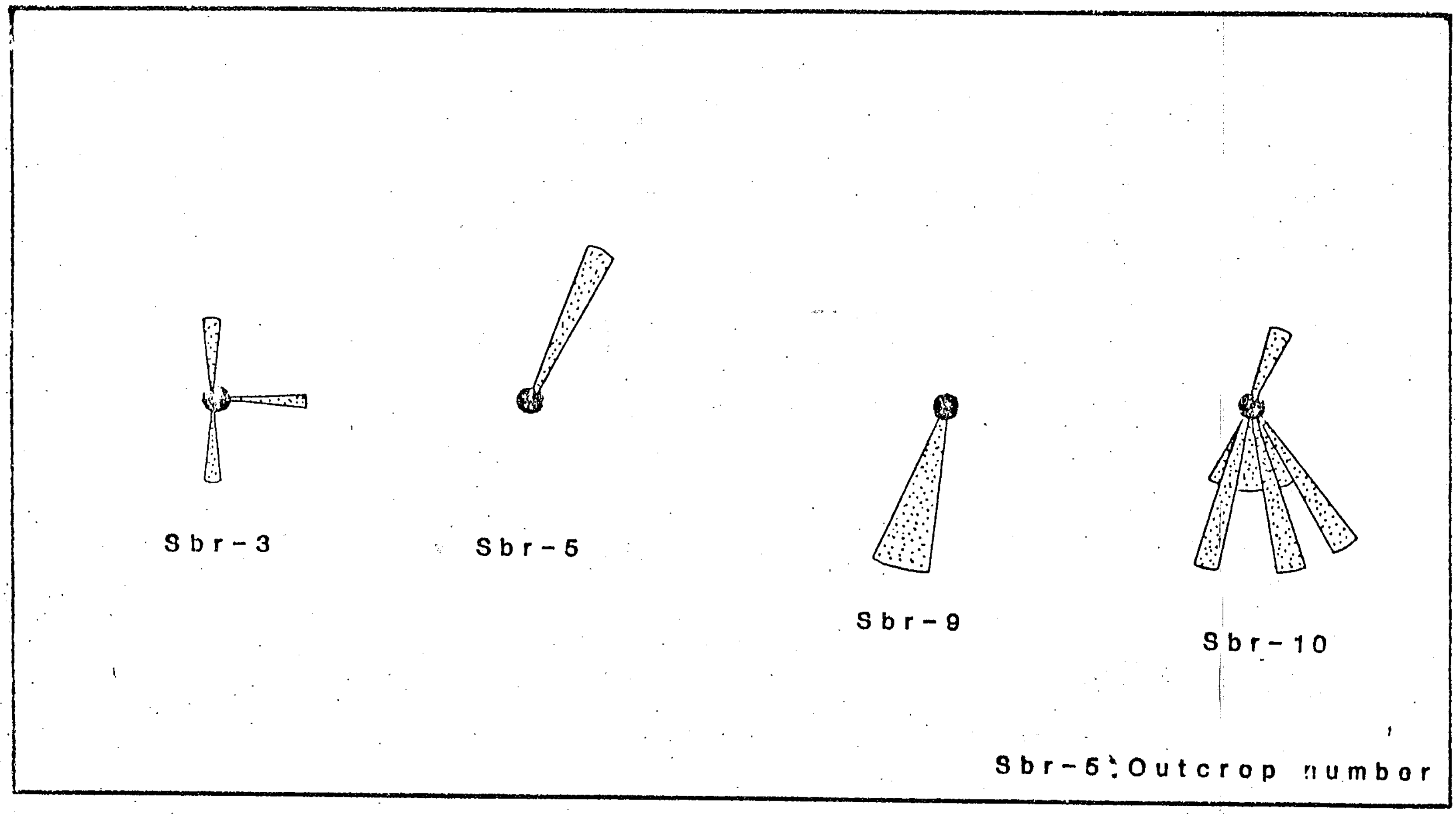
Current roses of the cross-stratification in the Angaraveca-El Zumbador section



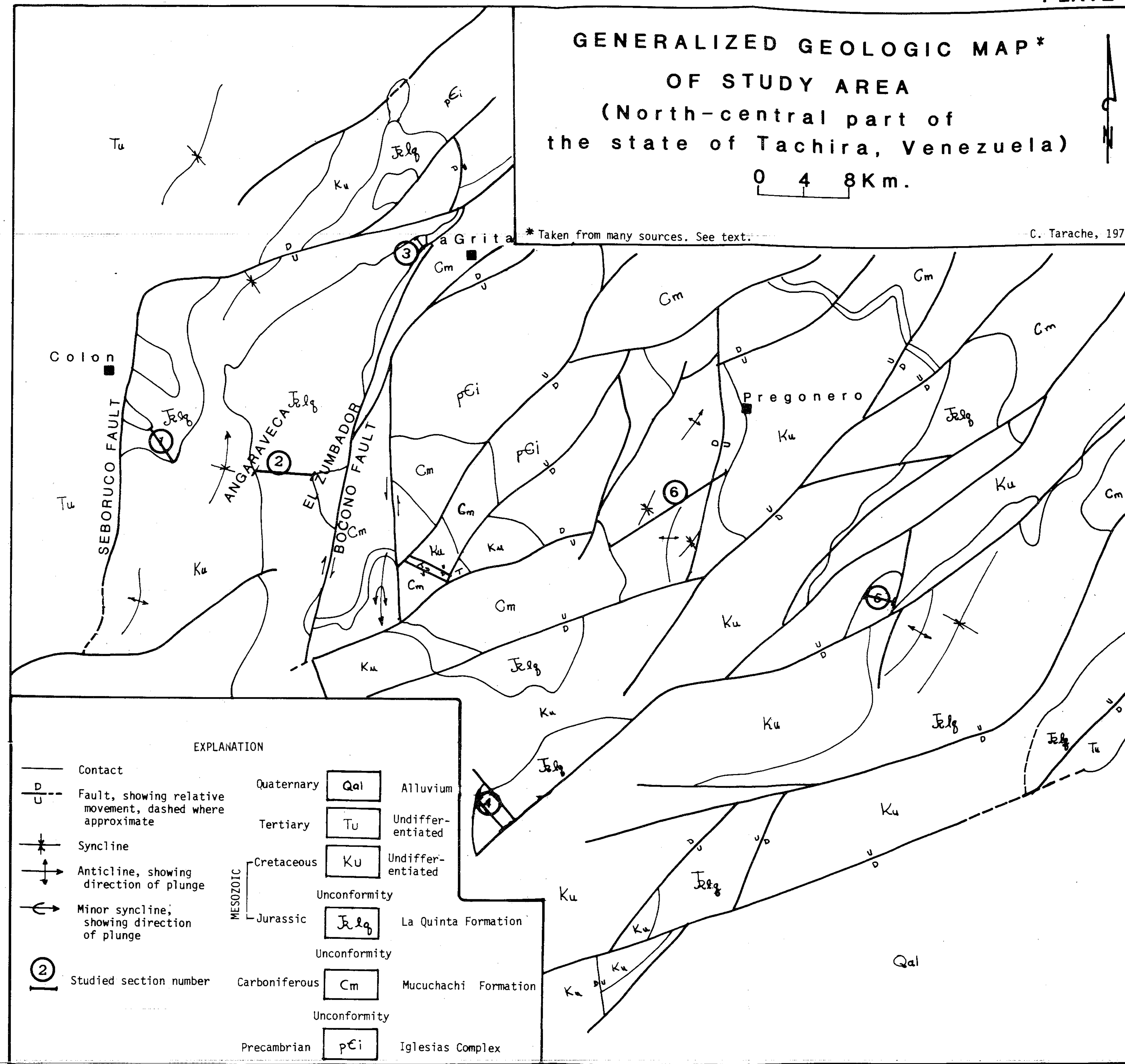
Current roses of the cross-stratification in the Angaraveca-El Zumbador section



Current roses of the cross-stratification in the La Pulida section

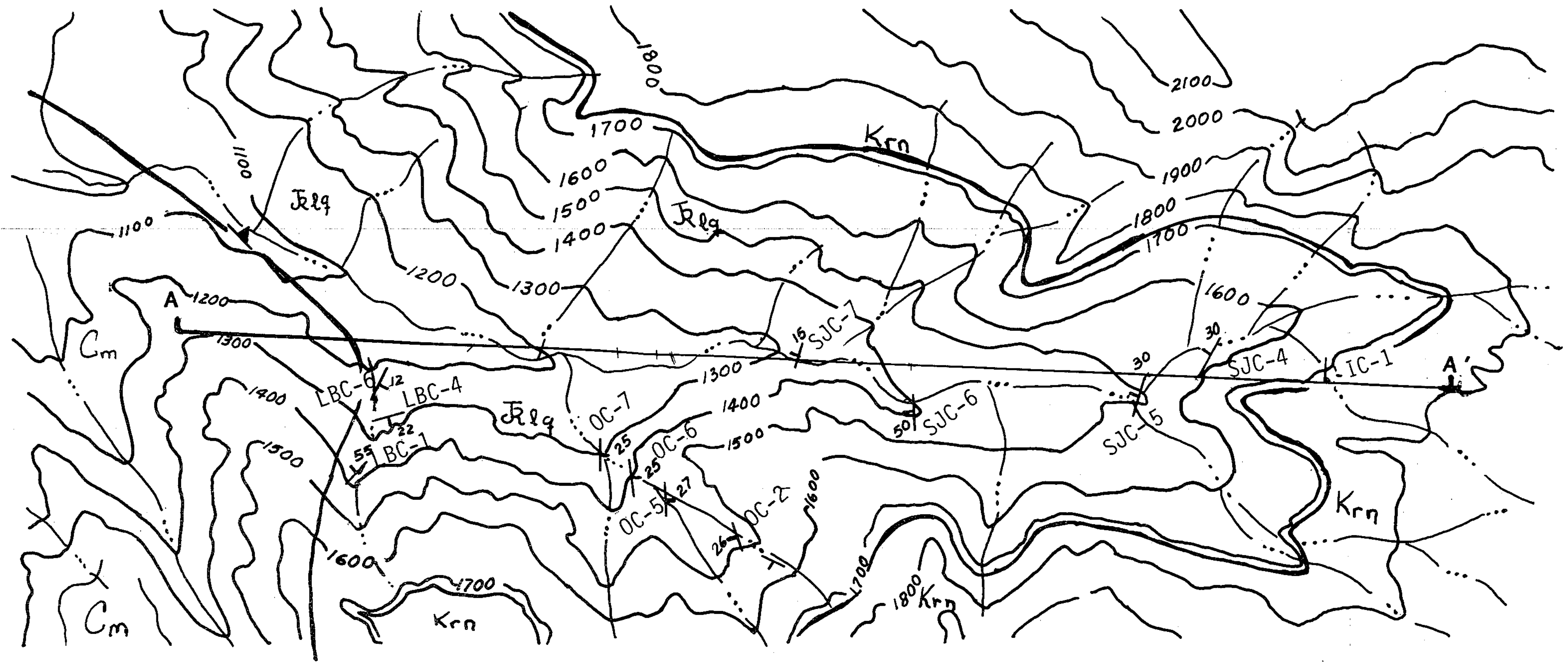


Current roses of the cross-stratification in the San Buenas section


GENERALIZED GEOLOGIC MAP*
OF STUDY AREA
(North-central part of
the state of Tachira, Venezuela)
0 4 8Km.
N
* Taken from many sources. See text.
C. Tarache, 1979
Colon
La Grita
Pregonero
SEBORUCO FAULT
ANGARAVECA
EL ZUMBADOR
BOCONO FAULT
Tu
Ku
Cm
pЄi
Qal
EXPLANATION
Contact
Fault, showing relative movement, dashed where approximate
Syncline
Anticline, showing direction of plunge
Minor syncline, showing direction of plunge
Studied section number
Quaternary Qal Alluvium
Tertiary Tu Undifferentiated
MESOZOIC
Cretaceous Ku Undifferentiated
Unconformity
Jurassic Jlq La Quinta Formation
Unconformity
Carboniferous Cm Mucuchachi Formation
Unconformity
Precambrian pЄi Iglesias Complex

SAN JUAN DE COLON

Geologic map and structural cross-section



EXPLANATION

0 500 1000 m.

N

Topographic symbols

2000 Contour — creek

Geologic symbols

Strike and dip

SJC-5 Outcrop location

A A' Cross-section

Conglomerate

Unconformity

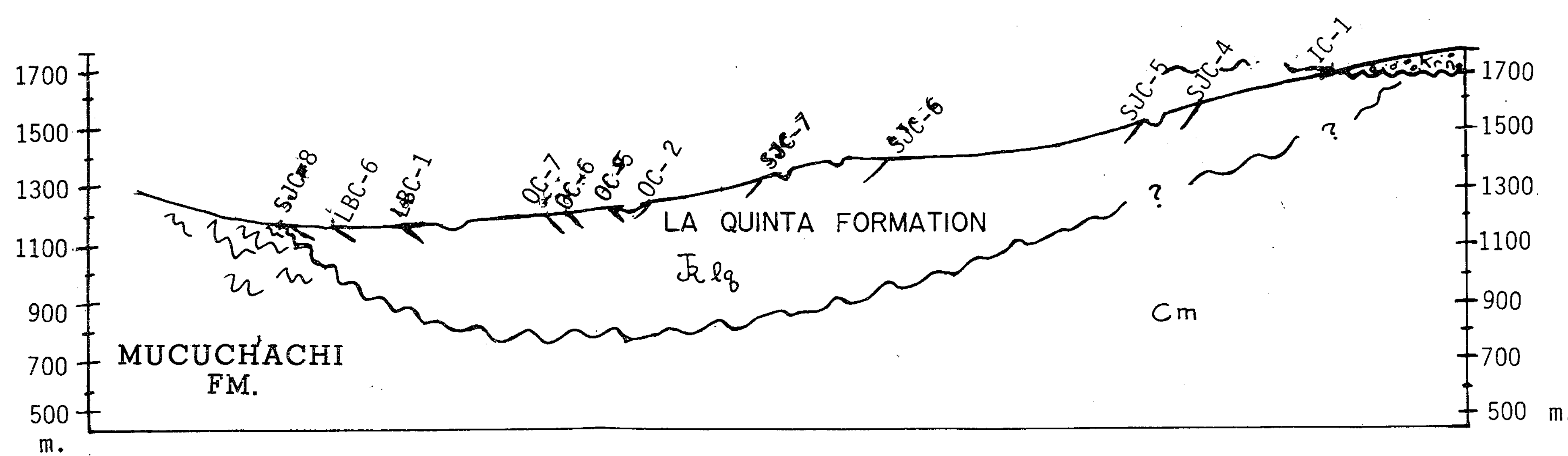
Form line

Contact

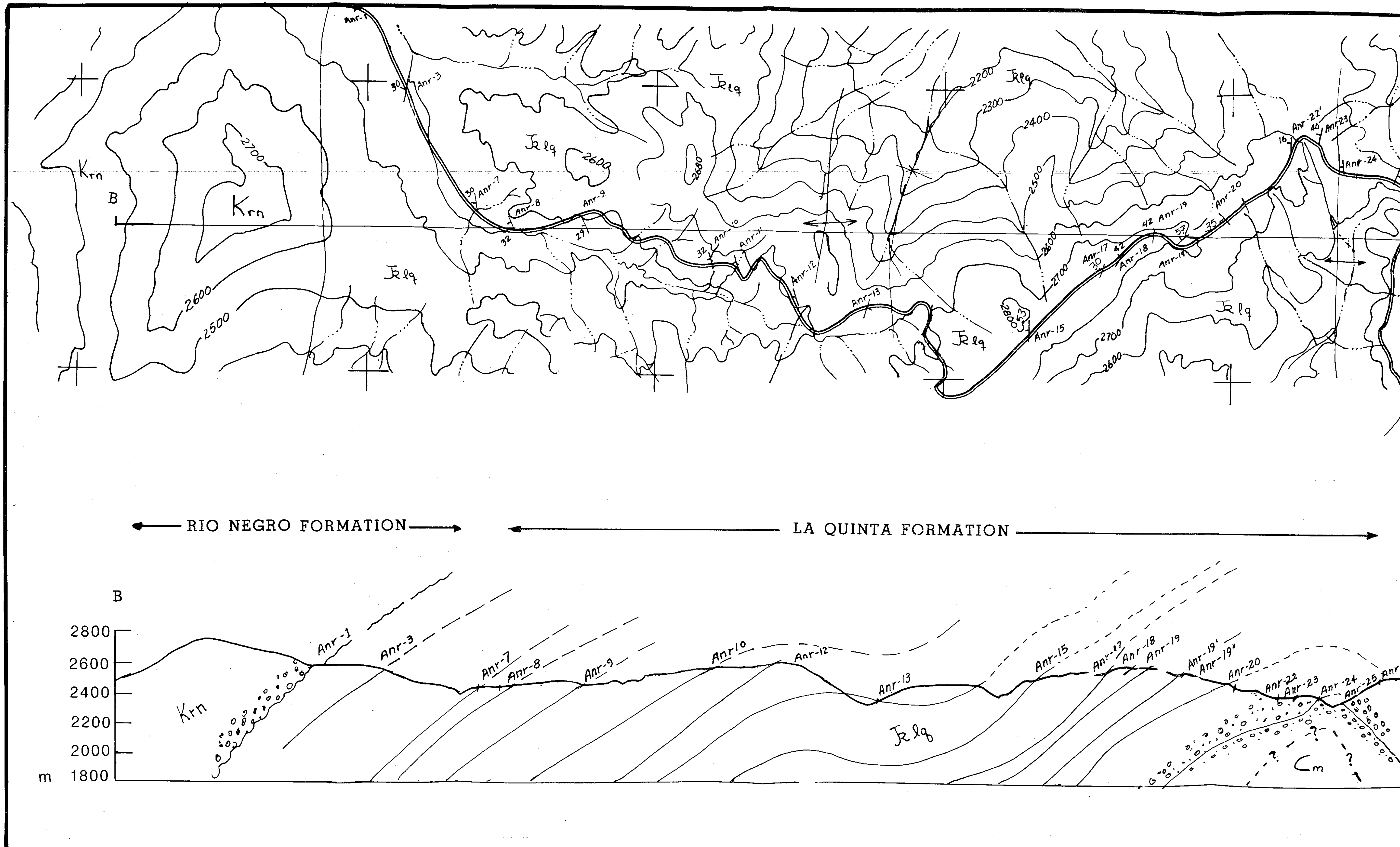
Cretaceous | Krn | Rio Negro Formation

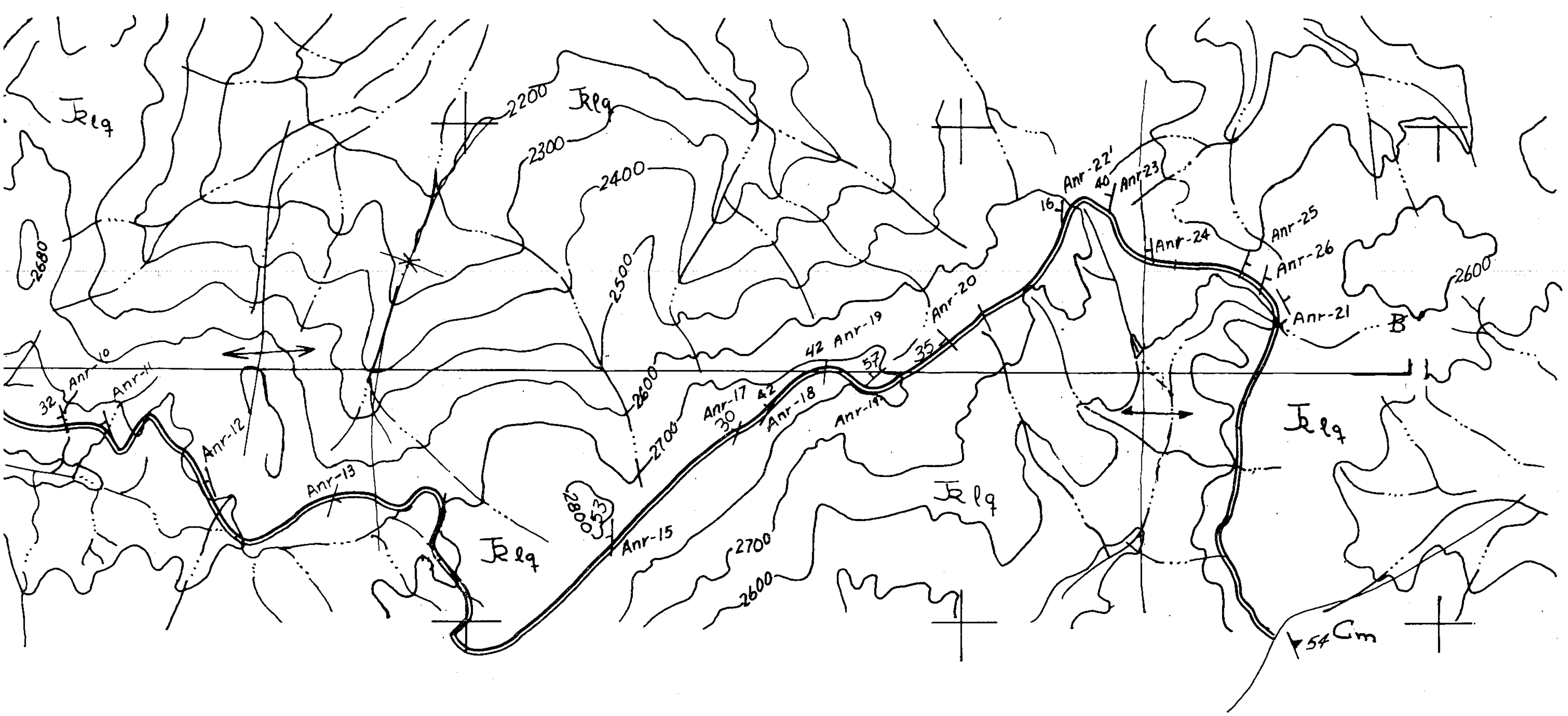
Jurassic | Jr lq | LaQuinta Formation

Carboniferous | Cm | Mucuchachi Formation

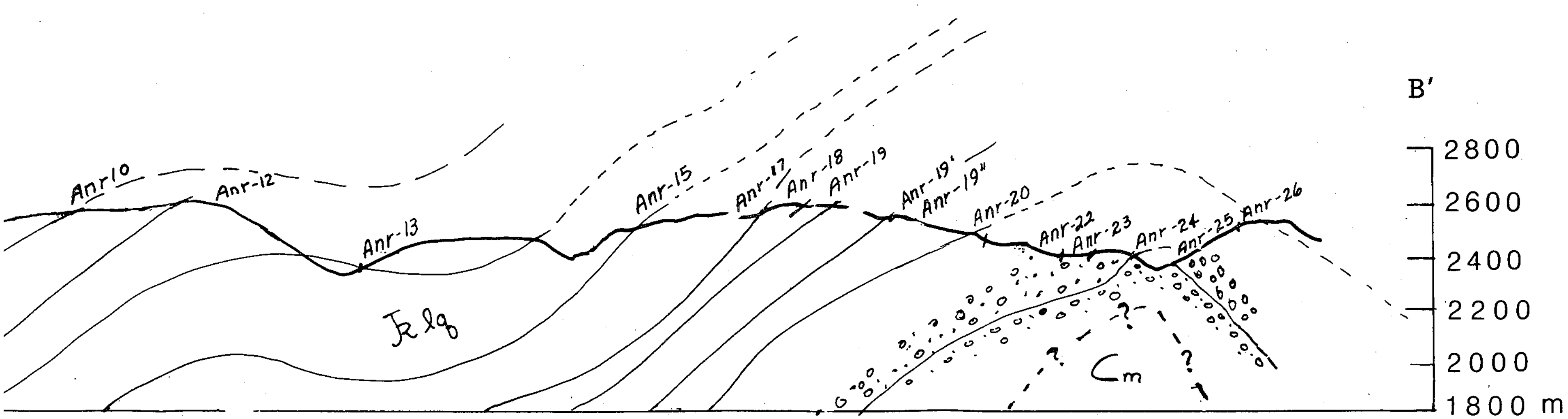


C. Tarache, 1979


Krn
Jklq
B
2800
2700
2600
2500
2400
2300
2200
2000
1800
m
Anr-1
Anr-3
Anr-7
Anr-8
Anr-9
Anr-10
Anr-11
Anr-12
Anr-13
Anr-15
Anr-17
Anr-18
Anr-19
Anr-19'
Anr-19"
Anr-20
Anr-22
Anr-22'
Anr-23
Anr-24
Anr-25
RIO NEGRO FORMATION
LA QUINTA FORMATION
Cm



LA QUINTA FORMATION



ANGARAVECA–EL ZUMBADOR SECTION

Geologic map and structural cross-section

EXPLANATION

0 500 1000 m

Topographic symbols

2600 Contour — road — creek

Geologic symbols

	Syncline		Anticline
	Form line		Unconformity
Anr-3	Outcrop location		Conglomerate
30	Strike and dip		Contact
		B B'	Cross-section

Cretaceous	Krn	Rio Negro Formation
Jurassic	Ᵹlq	La Quinta Formation
Carboniferous	Cm	Mucuchachi Formation

C. Tarache, 1979

CORRELATION OF FIVE MEASURED SECTIONS OF THE LA QUINTA FORMATION

STATE OF TACHIRA, VENEZUELA

By Crisalida Tarache, 1979

Vertical scale 1:5000

Horizontal scale 1:100,000

PLATE 4

2249