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Application of glauconite and fossil palynomorphs in reconstructing the Liassic paleogeography just before the opening of the Gulf of Mexico

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Abstract

Red beds, conglomerates and salt were considered azoic and problematic rocks, but Paleopalynology and Inorganic Geochemistry proved to be useful for placing them in time and space. In the early last century, in Mexican NE region, only three Mesozoic red bed units were differentiated, dated as Late Triassic to Late Jurassic. It was important stratigraphically to place them properly as they were considered to be the basement of the marine petroliferous sequence in some Mexican Gulf of Mexico sub-basins. Palynostratigraphic studies since 1969, and X- ray analyses since 1989 allowed to place, in time and space, the Cahuasas, Huizachal, La Joya, and La Boca red bed units, outcropping at the Huizachal-Peregrina and Huayacocotla anticlinoria and, recently, the Rosario, Conglomerado-Prieto and Cuarcítica-Cualac units at the Tlaxiaco Anticlinorium. For reconstructing the paleogeographic distribution of these red beds, their correlation permitted to place the Liassic units as deposited in a half-graben connected to an Epicontinental Sinemurian Sea. This sea, during the Middle Jurassic, was invaded by the Tethysian waters through the Hispanic Corridor formed across the new Gulf of Mexico, which originated by a hot spot with a triple junction origin.

Keywords: *Glauconite, Palynostratigraphy, X- ray analyses, Gulf of Mexico Origin.*

1. Introduction

Based on their own lithologic characteristics, red beds, conglomerates and salt have been considered as azoic and problematic rocks. Nevertheless, Paleopalynology and Inorganic Geochemistry proved to be two very useful sciences in order to place red beds in time and space [1-10]. This introductory text is an abstract of all these articles, using some of the Figures, of the published article in the 1999 special paper 340, from the Geological Society of America Red bed and salt units are found in Mexico, distributed from the Paleozoic to Tertiary (Fig. 1), outcropping and in subsurface, mainly around the Gulf of Mexico basin. Mesozoic red beds are well exposed mainly in the core of the Sierra Madre Oriental (Fig. 2), which is the occidental margin of the oil and gas productive Mexican basins and formed by three main anticlinoria (Fig. 3).

During the early part of the last century, in the Mexican NE region (Huizachal-Peregrina and Huayacocotla anticlinoria and Tampico-Misantla Basin), three Mesozoic red bed units were differentiated (Huizachal, La Joya and Cahuasas) and chronologically placed from Late Triassic to Late Jurassic (Fig. 4).

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2-The Application of the Palynostratigraphic Method

As they were considered to be the basement of the marine petroliferous sequences in some Mexican Gulf of Mexico sub-basins (Fig. 3), it was stratigraphically important to place red beds properly, where they were found not alone, but as a part of sedimentary sequences exposed in anticlinoria (Fig. 4). Accordingly, since 1969 [12], palynological analyses allowed to place the Cahuasas Formation in early Middle Jurassic, in the Tampico-Misantla sub-basin (Fig. 3), bounded by unconformities over and under marine stratigraphic units [10].

During 1988-1994, the Huizachal and La Joya red bed units, outcropping at the Huizachal-Peregrina Anticlinorium (Fig. 5) were palynostratigraphically analysed [1-8]. More than 350 rock samples were obtained from sequences outcropping in 5 canyons and in the Huizachal dome (Fig. 6).

The main field lithological data were related to vertical grain size and carbonates content variation in a rhythmic red bed sequence, composed of conglomerates, sandstones and siltstones. Carbonates content was considered the first possible evidence of marine environments among this red bed succession (Fig. 7).

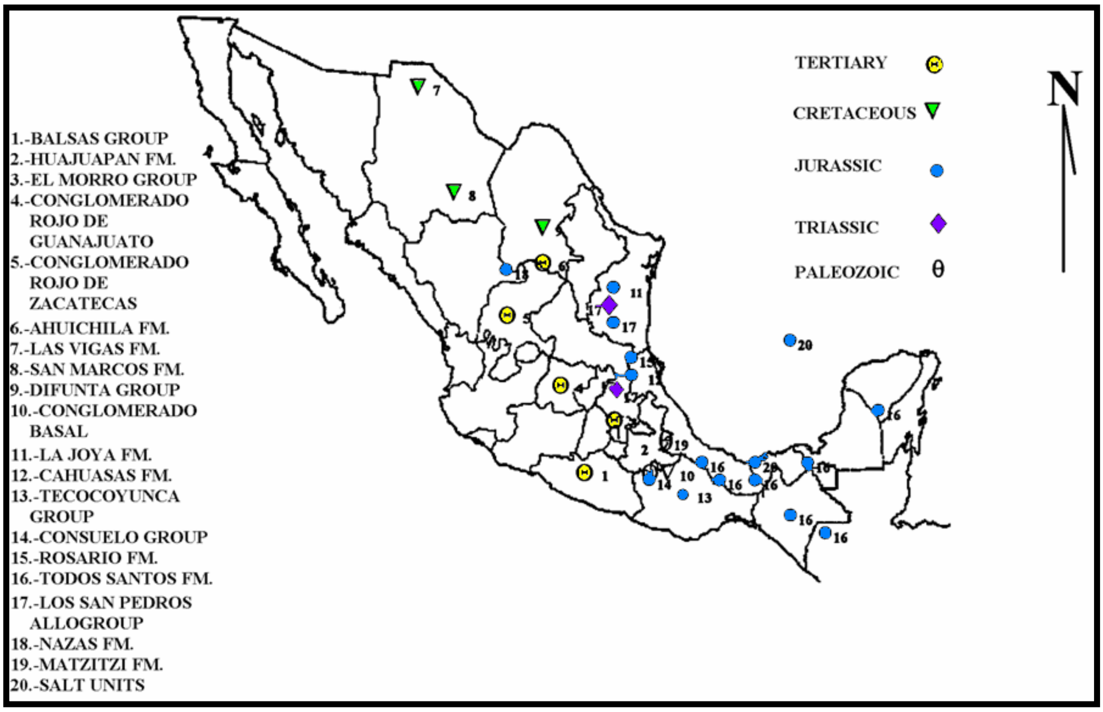

Fig. 1.Location of Mexican red beds and salt units [11].

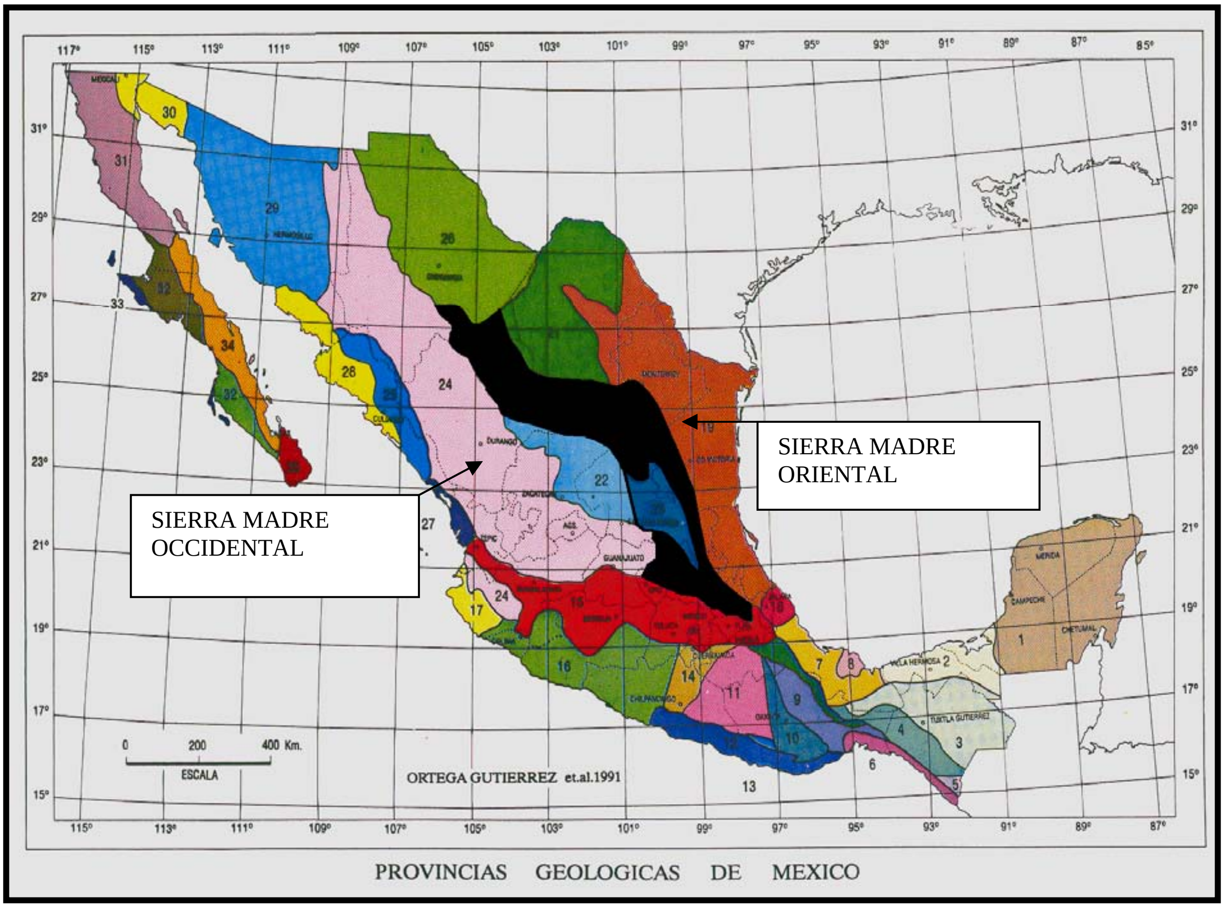

Fig. 2. Map of Geological Provinces of Mexico shows the position of the main sierras in Mexico

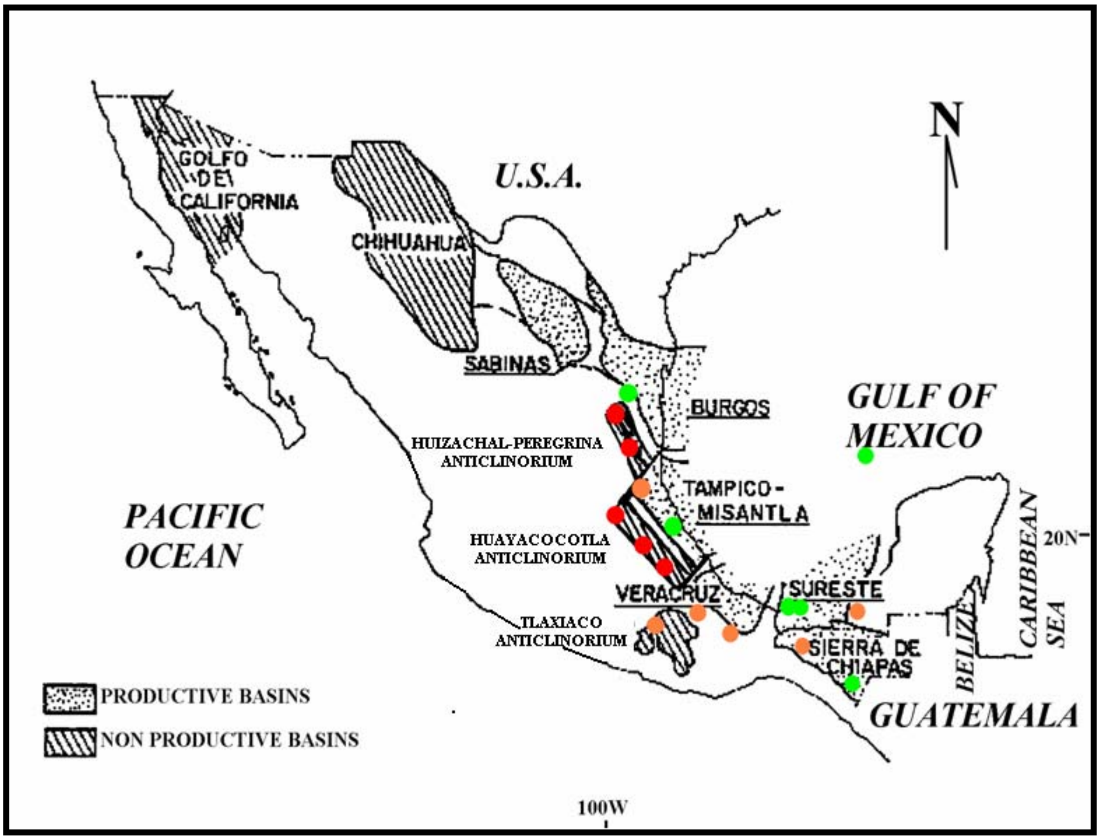

Fig. 3. Anticlinoria, oil productive and non productive Mexican basins

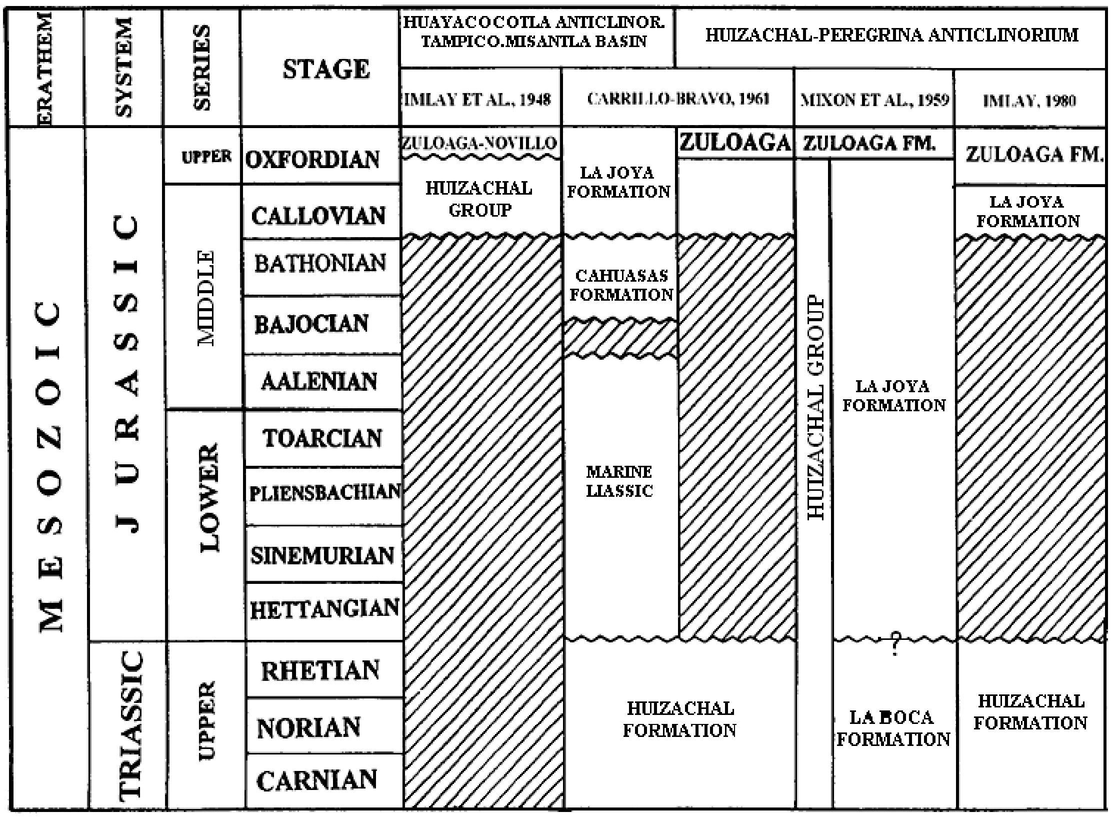

Fig. 4. Ancient chronostratigraphic position of red beds in NE Mexico

Fig. 5. The Huizachal-Peregrina Anticlinorium at the Sierra Madre Oriental in the Mexican Geologic Map

The main field lithological data were related to vertical grain size and carbonates content variation in a rhythmic red bed sequence, composed of conglomerates, sandstones and siltstones. Carbonates content was considered the first possible evidence of marine environments among this red bed succession (Fig. 7). Lithologic field description and palynological results (see "the basis of Palynostratigraphic Method" in [13]) showed the existence of not two but three superposed red bed units, dated and characterized by palynomorphs and palynological residues: Huizachal (Late Triassic-Hettangian?) and La Boca (Sinemurian-Pliensbachian) alloformations and La Joya Formation (Callovian). Both alloformations are separated by a low angle unconformity.

Based on the application of Facies Analyses [14], petrographic composition and on the basis of 8 palynozones established by colour and abundance of palynological residues, the sequences of red bed rocks from the La Boca Canyon and the La Escondida (at Huizachal Dome) were subdivided into three red bed units: Triassic Huizachal (Palynozone A), Sinemurian-Pliensbachian La Boca (Palynozones B-F) alloformations (conforming the Los San Pedros Allogroup) and Callovian La Joya Formation (Palynozones I and II). These units are bounded unconformably by the Permian Guacamaya and Oxfordian Zuloaga marine formations (Fig. 7). La Boca Alloformation shows coarser grain conglomerates at the base and the top of sequence and fine sandstones and siltstones in the middle, where the carbonate content is higher. The very important Sample 359 was collected at the border between C and D palynozones.

The characterization of red bed palynozones permitted us to correlate the lithological sequences measured and sampled into canyons and dome from Huizachal-Peregrina Anticlinorium. Also, the dark brown and black colours of palynological residues and the orange and brownish colours of ethyl glycerinated alcohol in which the palynological residue is conserved (Fig. 7), were good evidences of presence of soluble organic matter (mainly aromatic hydrocarbons) in carbonate rocks from this red bed sequence [15].

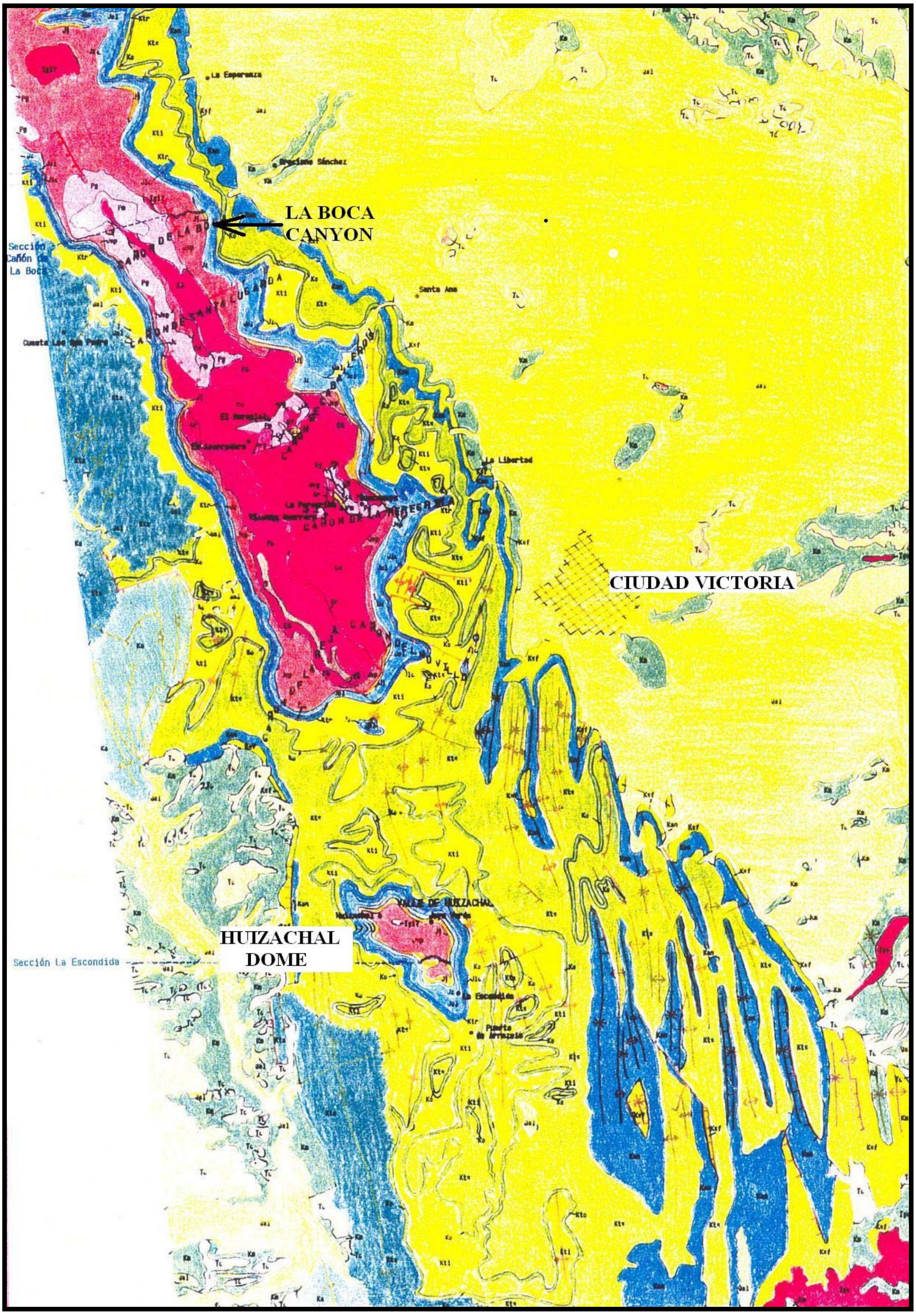

Fig. 6. De la Boca Canyon and Huizachal Dome locations at the Huizachal-Peregrina Anticlinorium. At the northern region, near Ciudad Victoria, Pre-cambrian to Cretaceous rocks outcrop; in the Huizachal Dome only Mesozoic rock are seen.

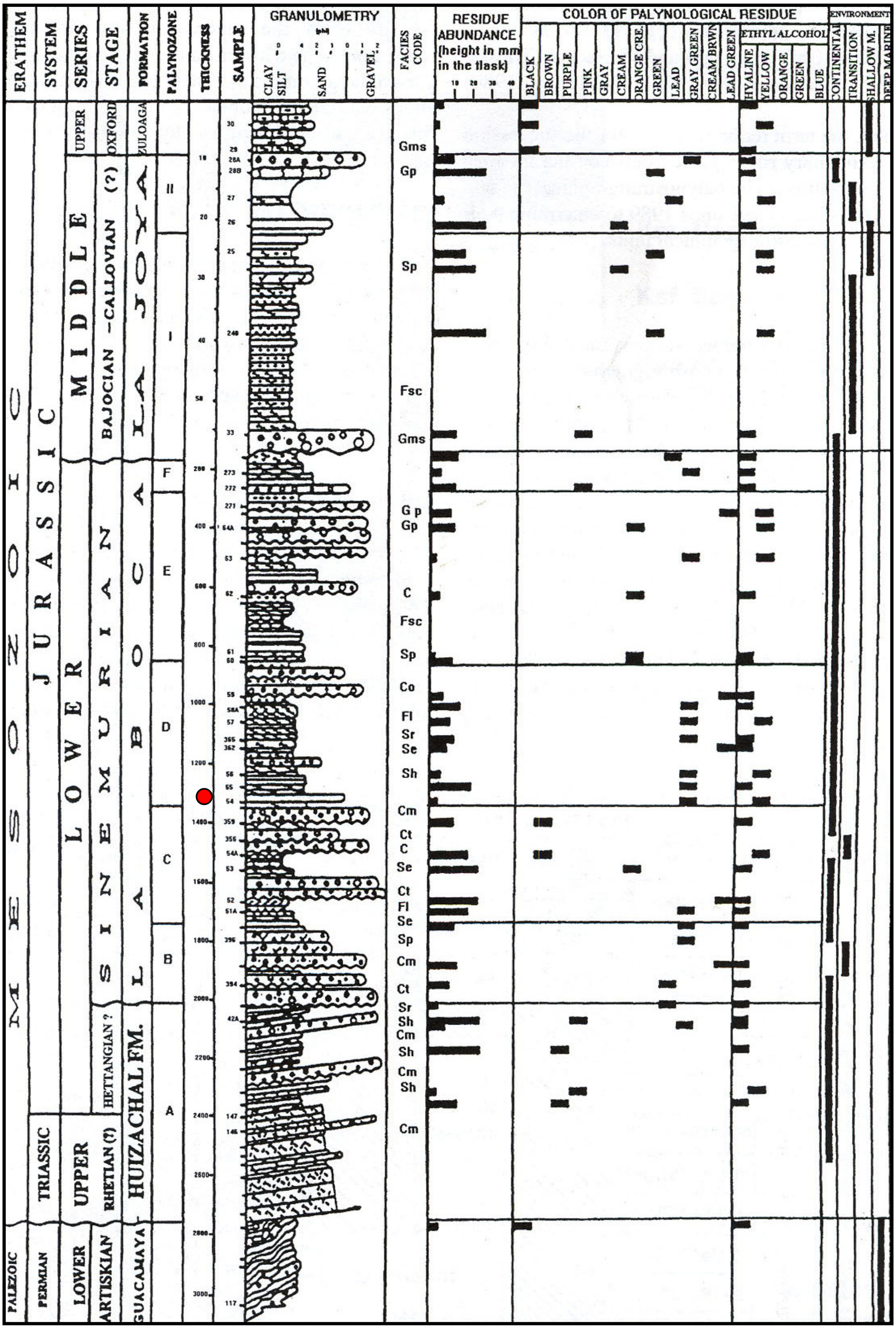

Fig. 7. Position of sample 359 (red circle) in the red bed palynozones from La Escondida-La Boca composite sequence, based on rock samples, facies code and colour and abundance of palynologic residues. Columns on the right shown the colour of ethyl alcohol and depositional environment (continental, transitional, shallow and deep marine) deduced after the analyses of lithological and palynostratigraphical data based on [13.]

Also, above the base of La Boca Alloformation, among fine grained rocks with high carbonates content (Figure 7), the palynological slides made with an abundant palynological residue, dark coloured, from sample 359, showed algal matter and marine and continental palynomorphs: dinoflagellates cysts, acritarchs, pollen and spores (Figures 8 and 9); these were the most valuable palynological evidences of marine sedimentary conditions during the Sinemurian-Pliensbachian Time [4] and [10].

The principal classified palynomorphs are almost the same as in Liassic rocks from all over the world; they are the following:

1.-*Dapcodinium priscum* EVITT 1961
2.-*Pareodinia* sp. DEFLANDRE 1947
3.-*Rhaetogonyaulax rhaetica* (SARJEANT 1963) HARLAND *et al.* 1975
4.-Cf. *Nannoceratopsis gracilis* ALBERTI emend. EVITT 1962
5.-Dinoflagellate sp. 2 MORBEY & DUNAY 1978
6.-Cf. *Sphaeropollenites* sp.
7.-*Krausellisporites reissingeri* (HARRIS 1957) MORBEY 1975
8.-*Dictyophillidites* sp. 1 MORBEY & DUNAY 1978
9.-*Araucariacites* cf. *australis* COOKSON 1947
10.-*Exesipollenites tumulus* BALME 1975
11.-*Exesipollenites tumulus* BALME 1975
12.-*Exesipollenites tumulus* BALME 1975
13.-*Classopollis* sp. (PFLUG) POCOCK & JANSONIUS 1961
14.-*Classopollis sp.* (PFLUG) POCOCK & JANSONIUS 1961
15.-*Eucommiidites troedsonii* ERDTMAN 1948
16.-*Vitreisporites pallidus* (REISSINGER) NILSSON 1958
17.-*Vitreisporites bjuvensis* NILSSON 1958
18.-*Eucommiidites troedsonii* ERDTMAN 1948
19.-*Ovalipollis breviformis* KRUTSCH 1955
20.-*Quadraeculina anallaeformis* MALJAVKINA 1949

The geochronologic distribution of these palynomorphs permitted us to date the La Boca Alloformation as Sinemurian-Pliensbachian (Fig. 10). As a general conclusion of this geologic and palynologic work, it was possible to determine the depositional environments for the lithological units (Fig. 11), and also to conclude that red bed sedimentation from the Los San Pedros Allogroup occurred in a half-graben, the Huizachal-Peregrina basin (Fig. 12), transgressed by marine conditions during Sinemurian-Pliensbachian Time [10].

3-The Application of the Inorganic Geochemistry

As the palynostratigraphic data were important but regionally isolated, it was difficult to use them for regional paleogeographic reconstructions. So, in order to prove the existence of an ancient marine environment among red beds, it was proposed that selected rock samples and palynologic residues from red bed units, be analysed by X- ray.

The first objective of the proposed Inorganic Geochemistry work was to verify or rectify the established Allogroup Los San Pedros paleogeography, based on data obtained from the Palynostratigraphic Method [13]. The second objective was to know the tectono-sedimentary relationships between this Allogroup and their under- and superimposed-stratigraphic units, using their Inorganic Geochemistry characterization at the Huizachal-Peregrina Anticlinorium red bed sequence [7].

3-1 Material and Methods

9 selected alcohol washed palynological residues (one of each palynozone), 119 outcropping rock samples from the Allogroup, 171 core samples from 24 wells drilled at E and SE from the Anticlinorium and 101 cutting samples from wells drilled at the northern region from the Tampico-Misantla Basin, known as Rosario Formation Sub-basin [16] were analyzed by X Ray diffraction and refraction techniques at the Mexican Petroleum Institute from 1989 to 1991. The used equipment was the Philips PW-1400 spectrometer (for X-Ray fluorescence: XRF) and the Philips APD-10 diffractometer (for X-Ray diffraction: XRD). Oriented and non-oriented powdered rock samples were used. Geological interpretation was based on Kübler [17, 18] and Chamley [19].

3-2 Elemental and mineralogical composition of the lithostratigraphic units

Inorganic geochemical data from X-ray fluorescence and X-ray diffraction analyses from **rock samples** proved very useful in correlation of the previously established palynozones with more distant stratigraphic sequences to the S and SE, because they permitted proper differentiation of each sedimentary lithological unit from Permian to Cretaceous.

X-ray analyses from selected **palynological residues,** representing those lithostratigraphic units, permitted us to identify a characteristic elemental and mineralogical composition for each unit and even for each palynozone (Fig. 13).

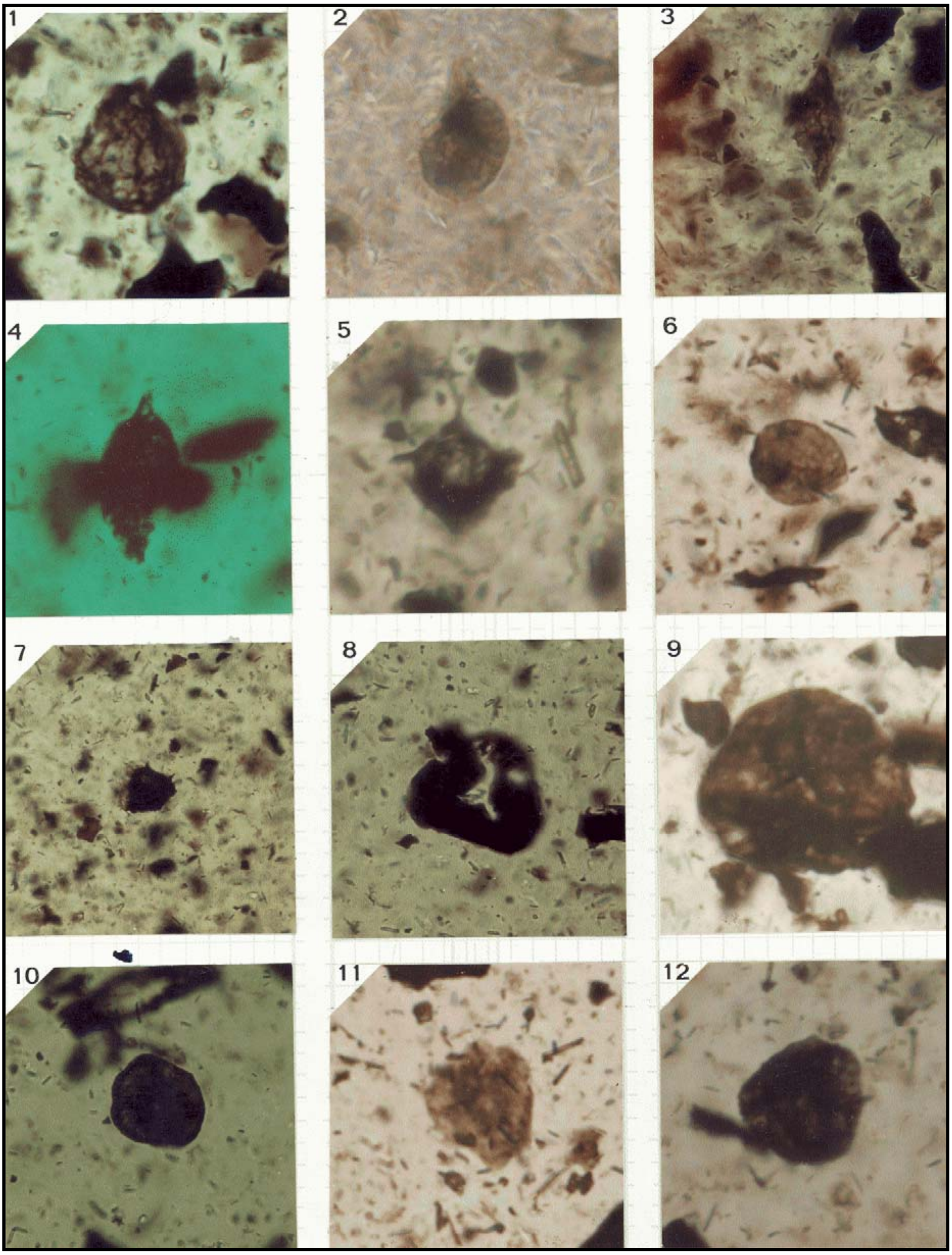

Fig. 8. *Sinemurian-Pliensbachian marine (1-5) and continental (6-12) palynomorphs content of sample 359. These are the best photos of palynomorphs, because they are the less carbonized dinoflagellates cysts and pollenospores deposited in a transitional oxygen rich environment*: 1.-*Dapcodinium priscum* EVITT 1961; 2.-*Pareodinia* sp. DEFLANDRE 1947; 3.-*Rhaetogonyaulax rhaetica* (SARJEANT 1963) HARLAND *et al.* 1975; 4.-Cf. *Nannoceratopsis gracilis* ALBERTI emend. EVITT 1962; 5.-Dinoflagellate sp. 2 MORBEY & DUNAY 1978; 6.-Cf. *Sphaeropollenites* sp.; 7.-*Krausellisporites reissingeri* (HARRIS 1957) MORBEY 1975; 8.-*Dictyophillidites* sp. 1 MORBEY & DUNAY 1978; 9.-*Araucariacites* cf. *australis* COOKSON 1947; 10.-*Exesipollenites tumulus* BALME 1975; 11.-*Exesipollenites tumulus* BALME 1975; 12.-*Exesipollenites tumulus* BALME 1975.

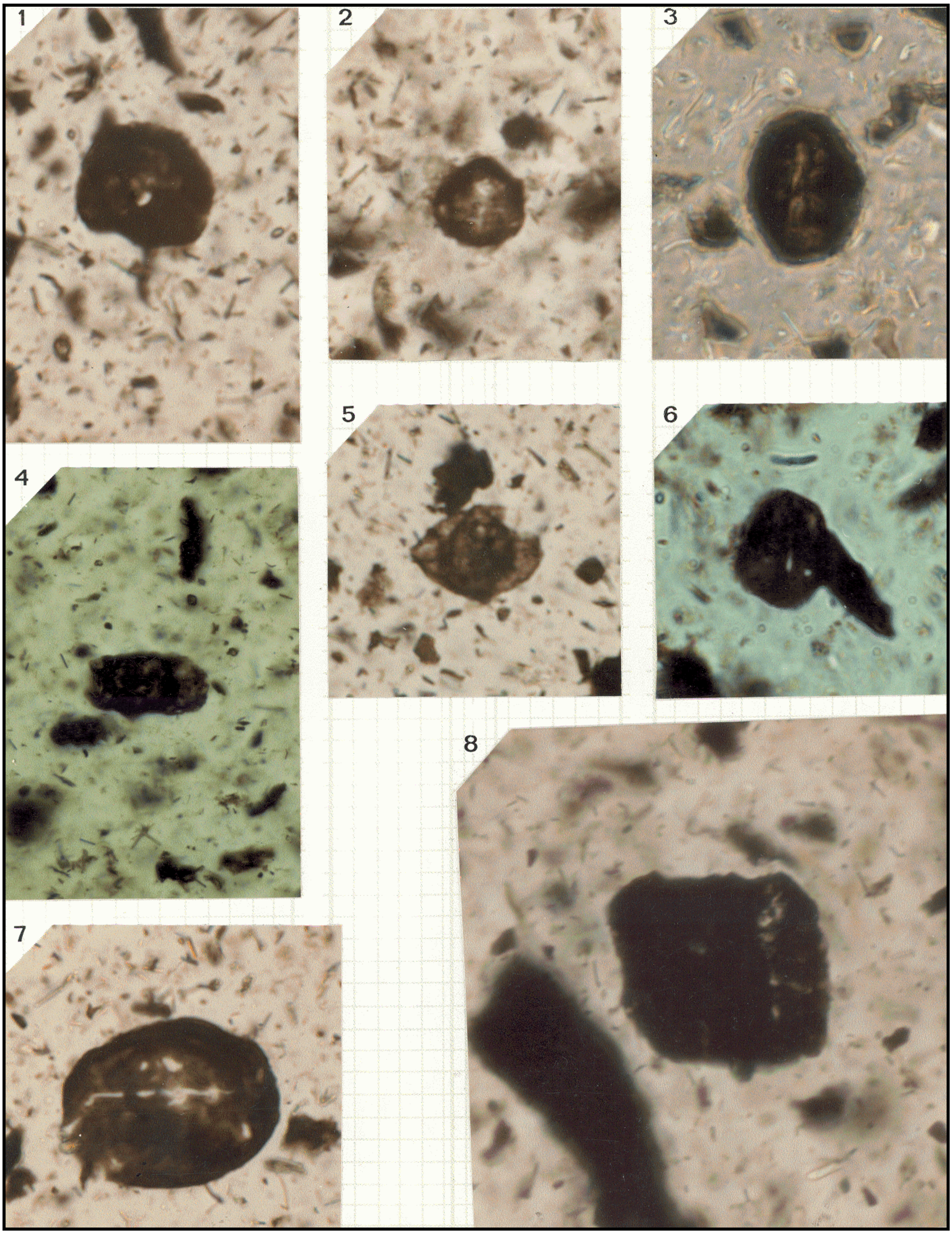

Fig. 9. *Sinemurian-Pliensbachian continental (1-8) palynomorphs content of sample 359. These are the best photos of palynomorphs, because they are the less carbonized pollenospores deposited in a transitional oxygen rich environment:* 1.-*Classopollis* sp. (PFLUG) POCOCK & JANSONIUS 1961; 2.-*Classopollis sp.* (PFLUG) POCOCK & JANSONIUS 1961; 3.-*Eucommiidites troedsonii* ERDTMAN 1948; 4.-*Vitreisporites pallidus* (REISSINGER) NILSSON 1958; 5.-*Vitreisporites bjuvensis* NILSSON 1958; 6.-*Eucommiidites troedsonii* ERDTMAN 1948; 7.-*Ovalipollis breviformis* KRUTSCH 1955; 8.-*Quadraeculina anallaeformis* MALJAVKINA 1949

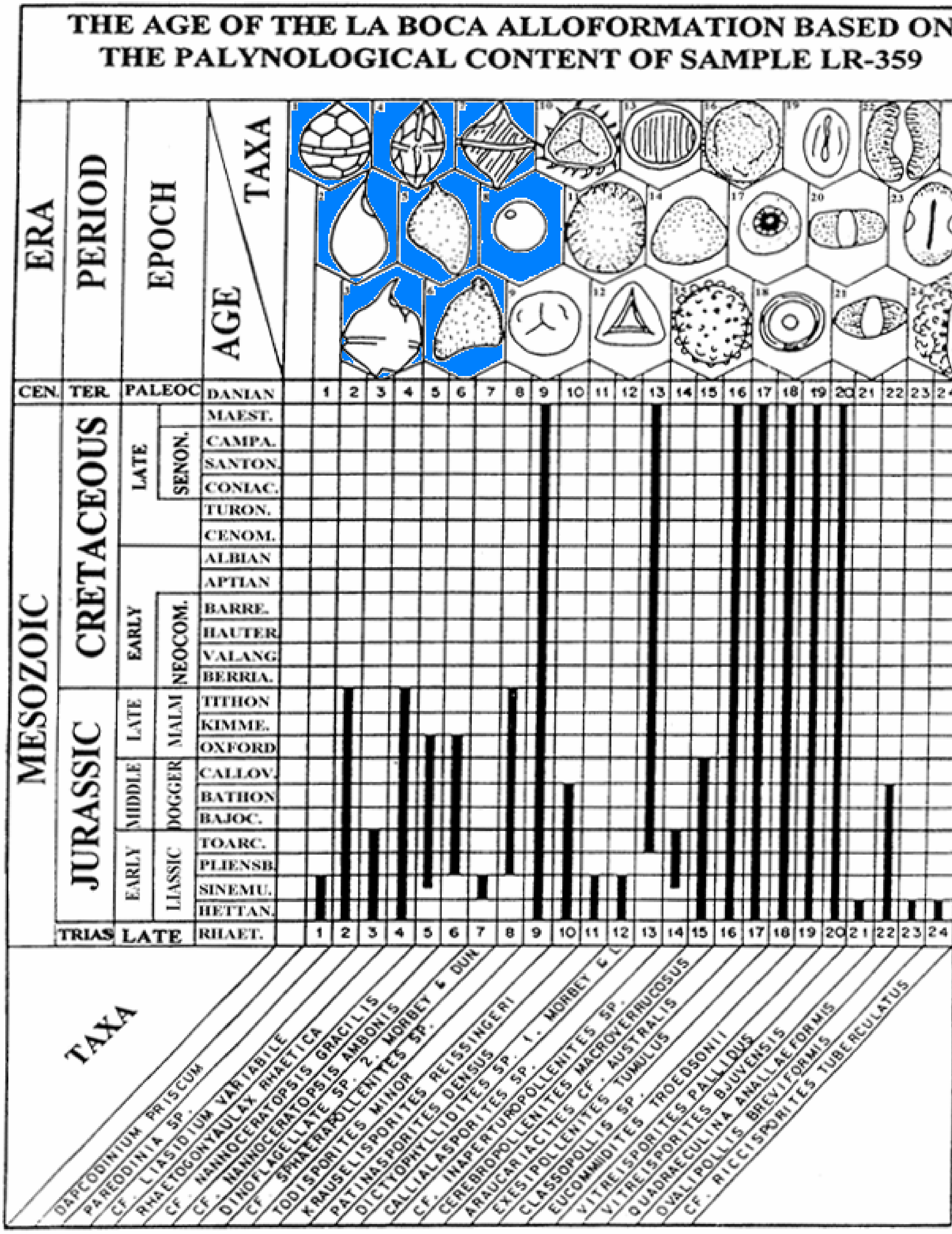

Fig. 10. *Sinemurian-Pliensbachian age, based on the marine and continental palynomorphs content of sample 359.*

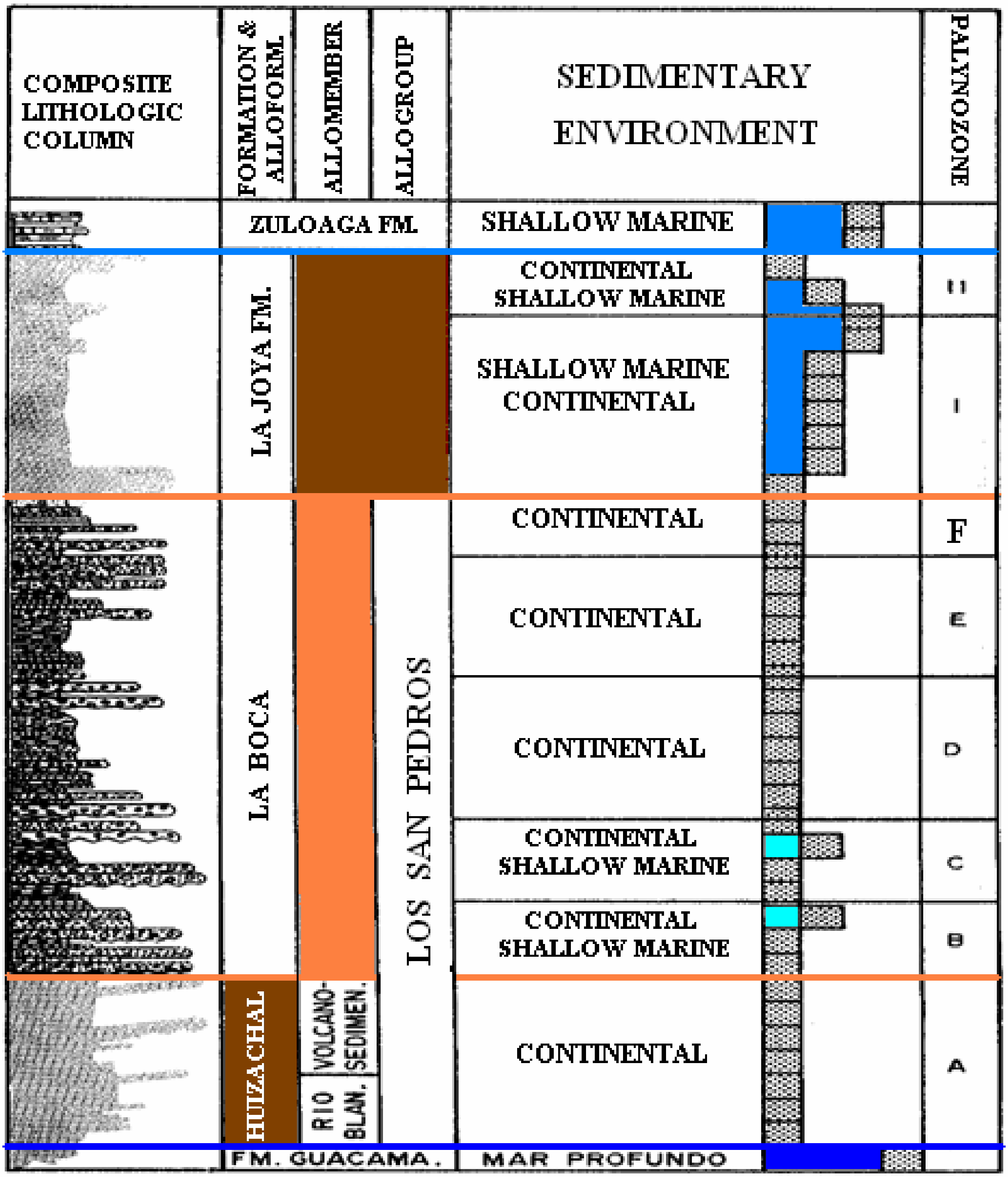

Fig. 11. Paleoenvironments deduced from lithologic data and marine and continental palynomorphs.

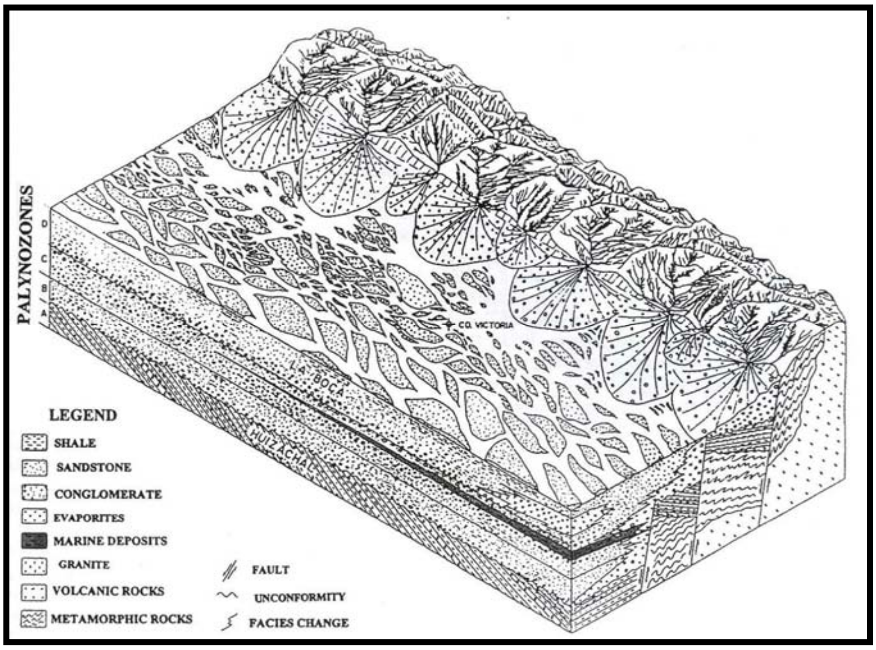

Fig. 12. Huizachal-Peregrina half-graben sedimentation, showing the marine transgression during the Liassic

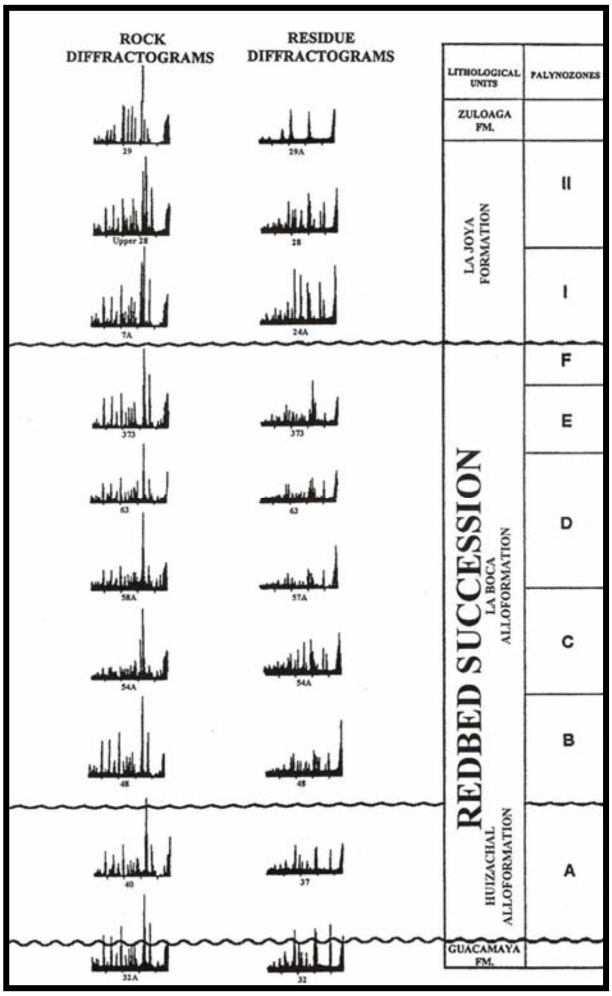

Figure 13. Characterization of lithological units by X- ray diffractograms

Some of these palynozones were represented by newly formed minerals found in palynologic residues. They originated during the attack of rock minerals by hydrochloric and hydrofluoric acids, used for obtaining the residual organic and inorganic matter from samples (see [8] and Fig. 14). For instance, the newly formed mineral hieratite was found in residues from transitional units such as La Joya Formation and the palynozones a and b from the Los San Pedros Allogroup; ralstonite was present in residues from more continental units as the Huizachal Alloformation and fluorite in residues from calcareous marine units as the Zuloaga Formation.

These X ray results (Fig. 14) successfully proved that the marine characterization of the Los San Pedros Allogroup was correct, because of the presence of glauconite (Fig. 14 and 15), dolomite and calcite in some greenish limolites and shales containing also abundant illite, just below the palynological sample with marine palynomorphs. They also proved that the palynological characterization and regional correlation of red bed units was correct, using the mineral and elemental contents obtained from X- ray analyses.

The presence of glauconite also in the La Boca Alloformation at the Huizachal Dome (Fig. 16), had a very particular importance due to the previous discovery, (during 1982) at that locality, of a mammal-like reptile [20] and [21] and other abundant vertebrate fauna [22] and [23] including the pterosaur *Dimorphodon weintraubi* Clark, J.M. *et al.* 1998 (Figures17-18). This genus of piscivore pterosaurs was first described after a Sinemurian fossil (*D. macronyx* Buckland, W., 1829) discoverd in the Blue Lias Limestone, to the East of Lime Regis, Dorset coast, England, near the Tethyan Sea [24]. The presence of another Dimorphodon at the Huizachal Dome required also the sea conditions, near this place as established by Glauconite and marine palynomorphs during Sinemurian Time in the half-graben of Huizachal-Peregrina Basin.

Following the statements of Chamley [19] and Kübler [17,18] the X- ray clay stratigraphic data were also used for the reconstruction of past tectonic, climatic, sedimentary and diagenetic events (Fig. 19) related to the evolution of Liassic Paleogeography before the Origin of Gulf of Mexico. Clays, non-argillaceous minerals, elemental composition and Detritic Index (D.I.) from the samples permitted us to differentiate lithostratigraphic units from Zuloaga Group, Los San Pedros Allogroup up to Guacamaya Formation [7]. Zuloaga and La Joya formations (Zuloaga Group) are different because the first one is an oligomineral and oligoelemental marine formation, with a low D.I. (0.33-0.40), deposited above a calcareous ramp during a temperate climate. The second one is a plurimineral and plurielemental transitional formation, with a higher D.I. (0.66), deposited during unstable tectonic conditions and a humid temperate climate.

On the other hand, Los San Pedros Allogroup is a plurimineral and plurielemental continental unit, with an increasing-decreasing upward D.I. (=0.29-0.45-0.19), due to the increasing basin stability during its rifting stage. The upper part was deposited in fluvial and deltaic conditions during an arid to humid temperate climate represented by hematite; the coastal marine conditions are represented at the middle part of the sequence, but chlorite, illite, mica and glauconite (Fig. 14), associated with calcite and dolomite, are present at the base of the sequence, where algal matter, and marine palynomorphs were previously identified and considered to prove the presence of marine transgressions during the initial deposition of the La Boca Alloformation.

These same minerals were detected in samples from the upper part of the underlying Huizachal Alloformation, and permitted us to obtain the same sedimentary conclusions but in a more oxygenated environment, characterized by abundant hematite. The lower part was deposited in a fluvial environment during the rifting tectonic stage and an arid to humid temperate climate. In general, the Los San Pedros Allogroup represents a transgressive-regressive sedimentary sequence.

The underlying Guacamaya Formation is also an oligomineral and oligoelemental marine unit, with a low D.I. (=0.29) characteristic of marine deposition but with a high continental influence due to the presence of plagioclases and quartz.

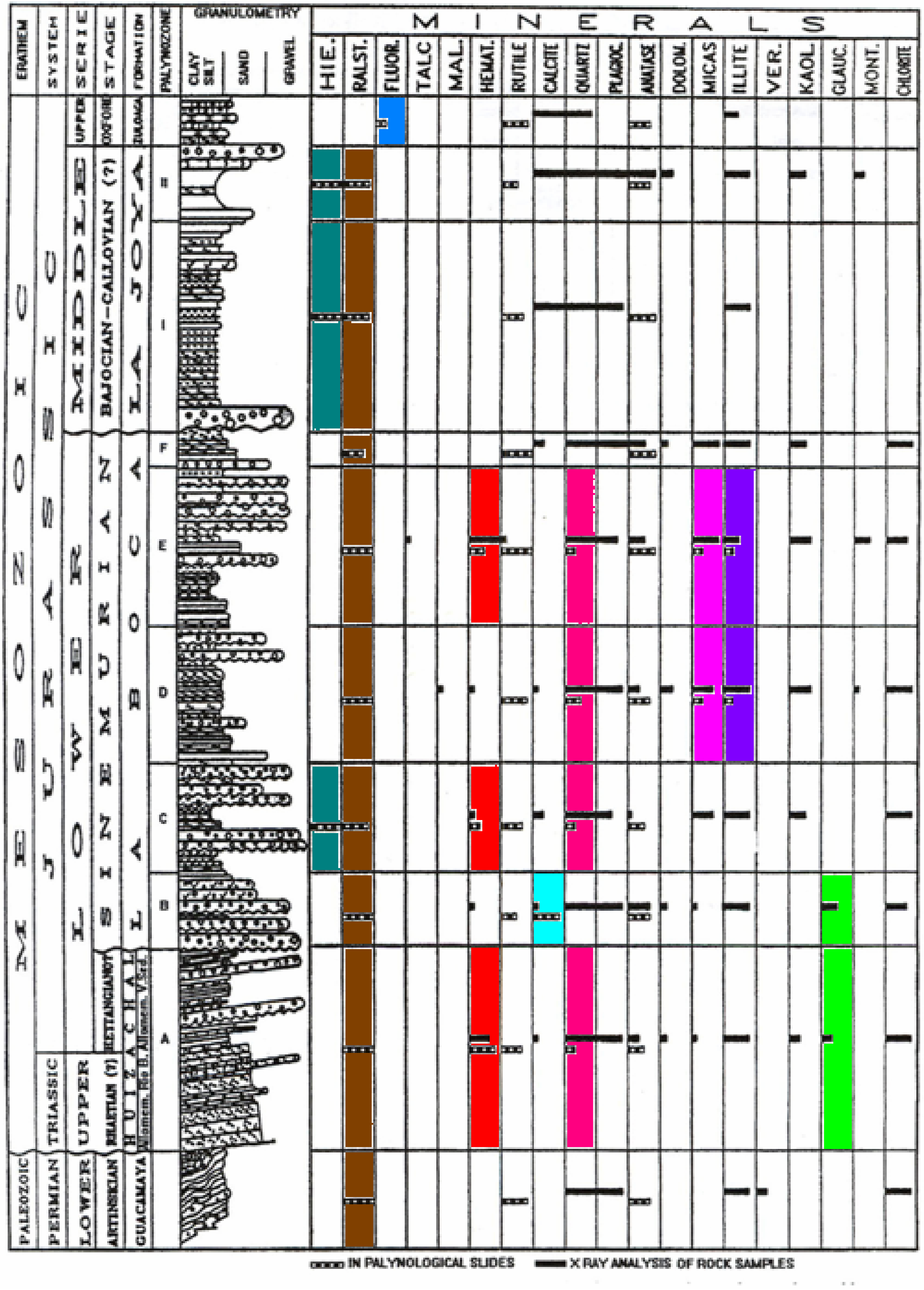

Fig. 14. Fluorite, Hieratite and Ralstonite were present in selected palynological residue samples. Hematite, Calcite, Quartz, Micas and Illite were present in both palynological residues and rocks. Glauconite was present only in rock samples from La Boca Canyon and Huizachal Dome. These minerals are very good environmental indices.

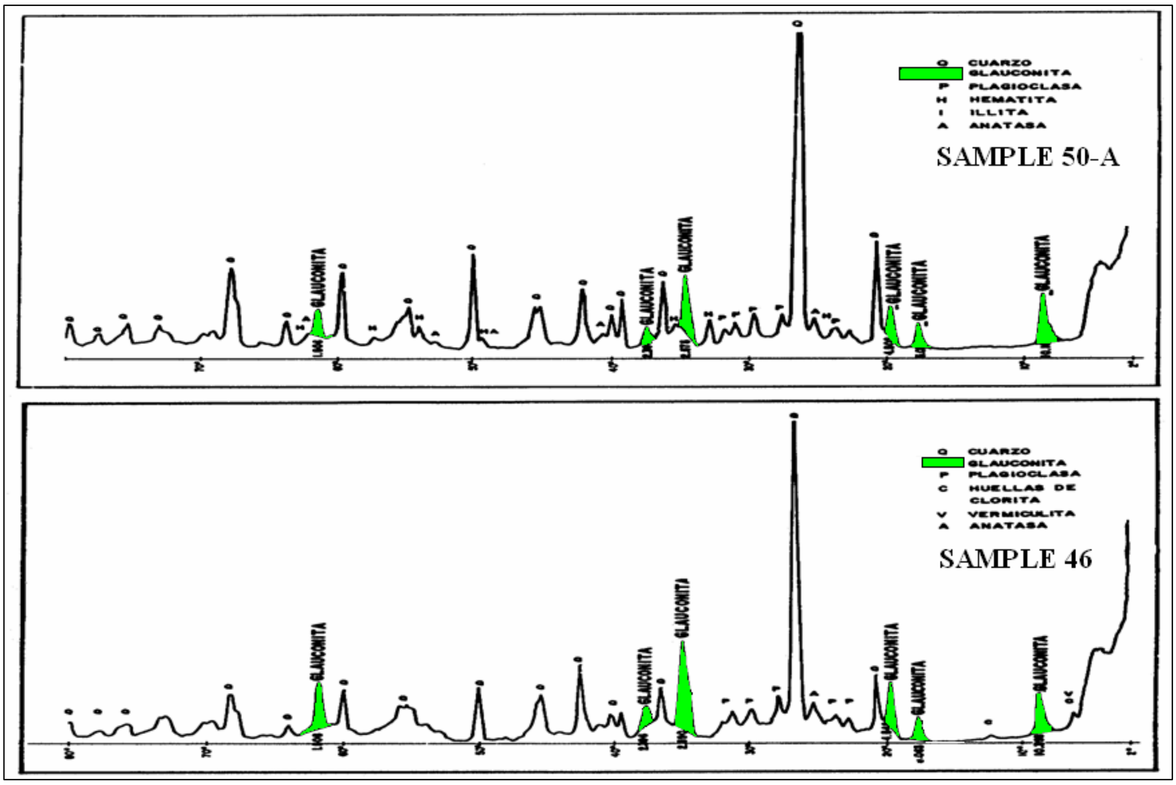

Fig. 15. Glauconite in red bed samples 46 and 50-A from La Boca Canyon

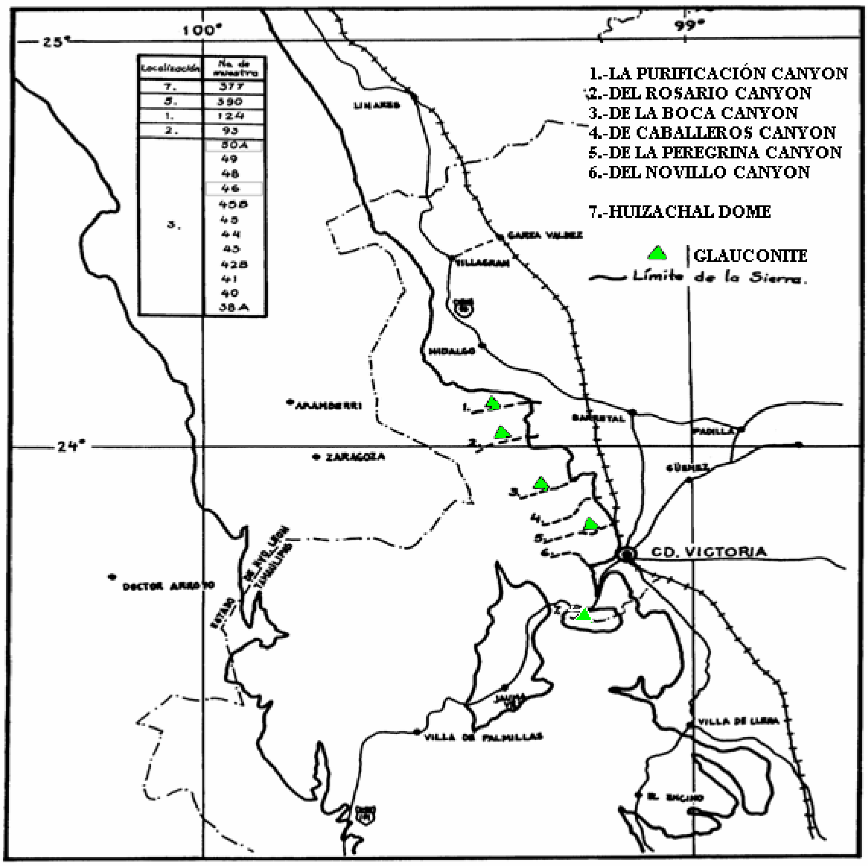

Fig. 16. Glauconite was found in five Huizchal-Peregrina Anticlinorium localities

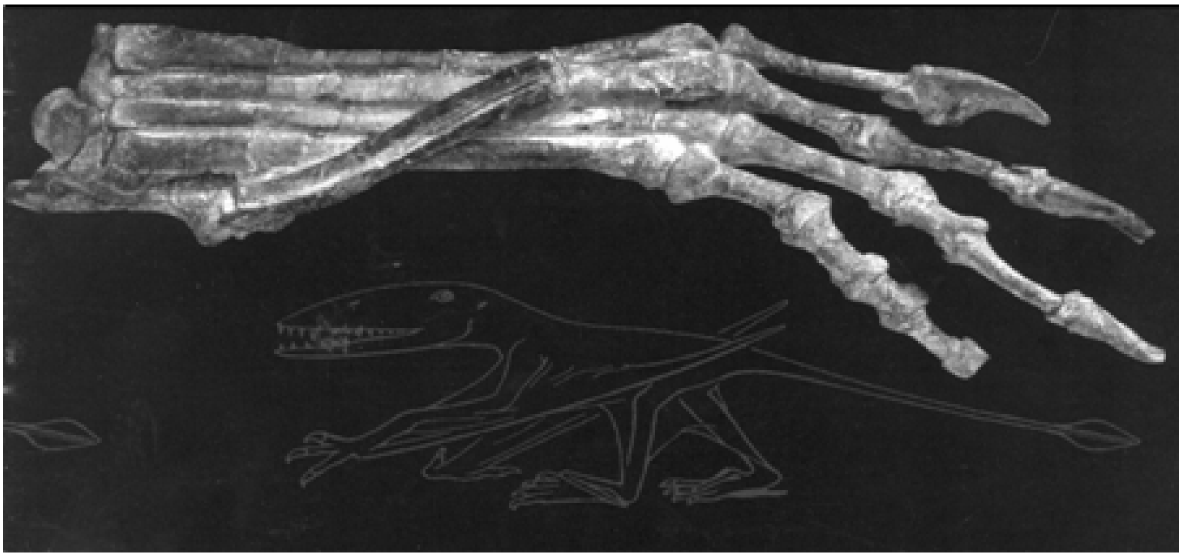

Fig. 17. The flat-footed pterosaur Dimorphodon weintraubi [23]

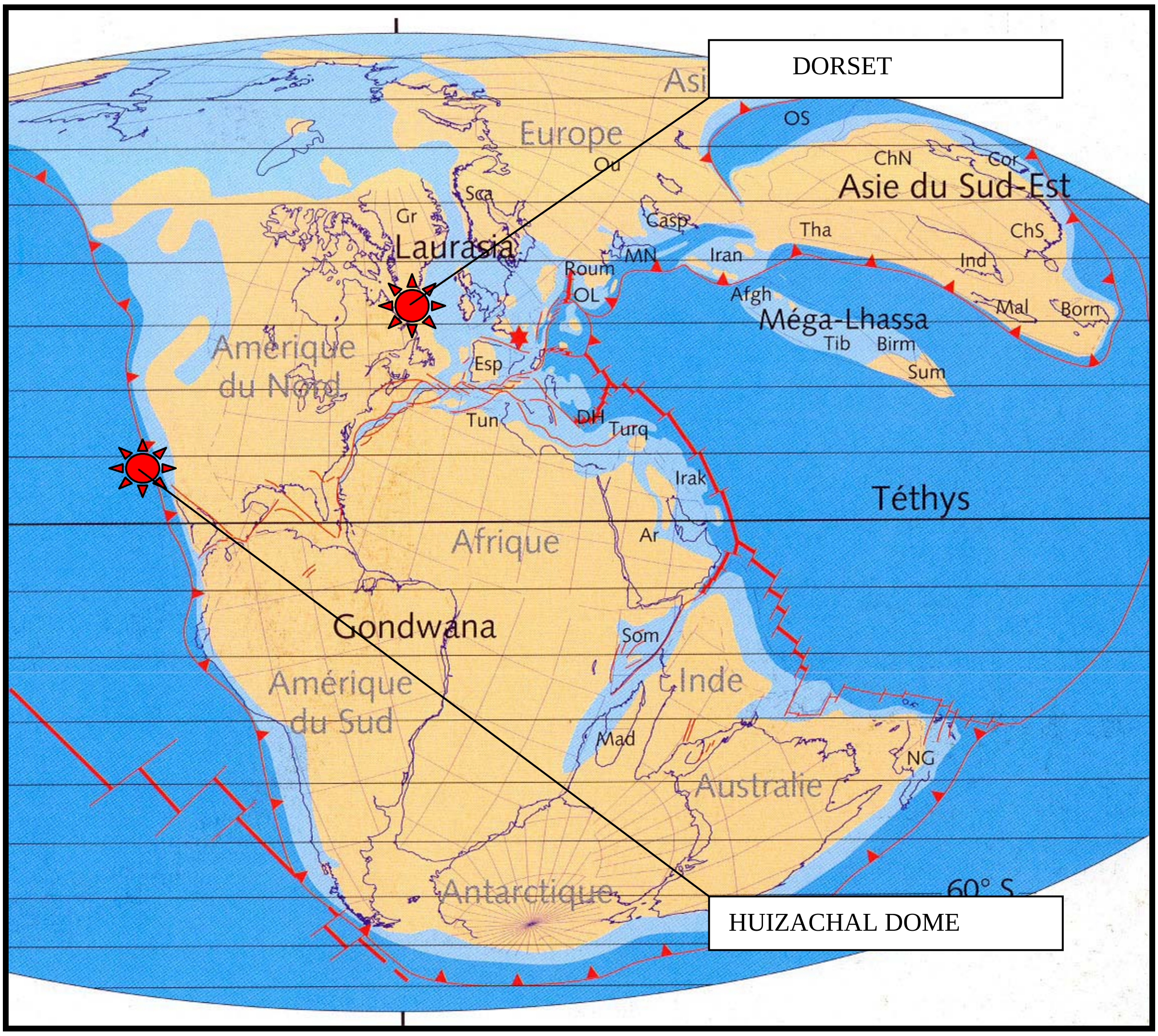

Fig. 18. Dimorphodon Sinemurian localities: Huizachal Dome and Dorset. Based on [25]

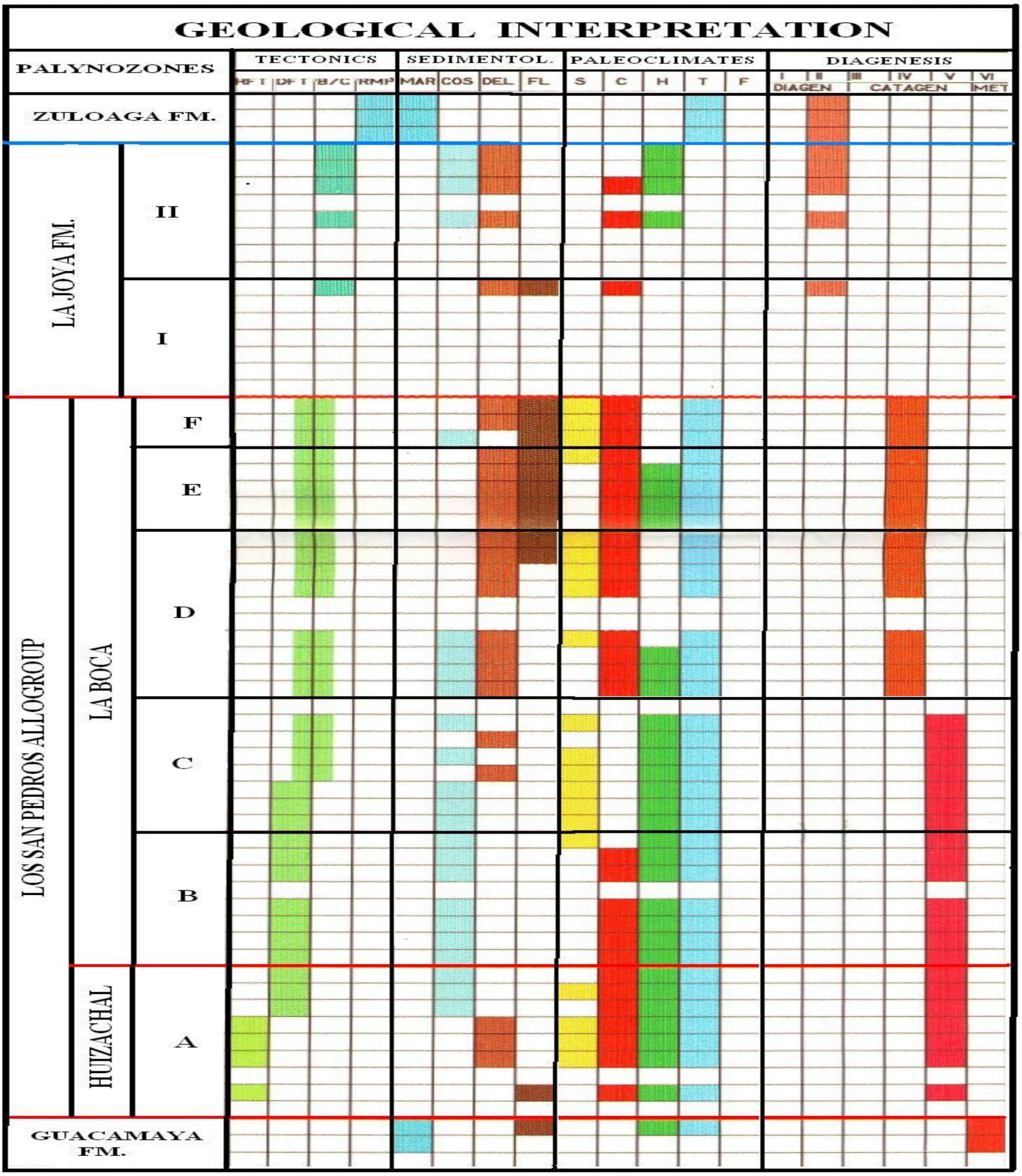

Fig. 19. Geological interpretation based on Chamley [19] and Kübler [17, 18]

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