THE AGE AND CORRELATION OF THE TERTIARY SEDIMENTS OF THE PARAGUANA PENINSULA, VENEZUELA[1]

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ABSTRACT

Two rich microfossil horizons have proven effective in subdividing the previously undifferentiated Tertiary sedimentary sequence of the Paraguaná Peninsula into at least two clearly separate Upper Tertiary depositional cycles. The older of the two horizons can be dated as Lower Miocene (Burdigalian) from rich foraminiferal faunas belonging to the Globigerinatella insueta and Praeorbulina glomerosa zones of Bolli (1966). This level includes the mollusc horizon at Casa Cantaure and a clarification and redescription of the type section of the Cantaure Formation is presented. The younger horizon represents the Lower Pliocene Globorotalia margaritae zone of Bolli and Bermudez (1965) and forms the basal shale of a largely Pliocene sedimentary unit described as the Paraguaná Formation. The sediments of this unit cover most of the surface of the peninsula and it is still not clear if Middle and Upper Miocene time is represented in the stratigraphic record of the area.

INTRODUCTION

Tertiary sediments cover most of the Paraguaná Peninsula ringing protruding basement igneous and methamorphic rocks in a serioes of concentric scarps reflecting seaward dips rarely exceeding 10 degrees. Minor structuring resulting from the differential compaction of the Tertiary sediments over an irregular basement can be observed (Feo-Codecido, 1971).

The first published descriptions appear to be those of Karsten (1850-1851) who, in noting their Tertiary age, compared the limestone levels with those of Cumarebo, Píritu, and Capadare in East Falcón. Sievers (1898) listed an abundant molluscan fauna from horizons south of Cerro Santa Ana which were determined as Upper Miocene by Moricke (see Jahn, 1921). Later, F. and H. K. Hodson (1931) published the first of several descriptions of the fossil mollusca from the Casa Cantaure area, west of San José de Cocodite.

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In their publication they considered these faunas as Lower Miocene in age and in private reports correlated this level more specifically with the Cerro Pelado Formation of Central and Western Falcón. Schilder (1939), when describing various species of Cypraeacea from the same locality, compared his forms with those of the St. Croix member of the Brasso formation of Trinidad, which is also Lower Miocene in age.

From these early observations it appears that two distinct levels could already be recognized within the Miocene of the Paraguaná Península. However, much later publications tended to reverse these early findings with the result that the ensuing uncertainty over specific age has deterred any attempt at clarifying the Tertiary depositional sequence of the Península. Doubt was already cast on Hodsons' determinations of the age of the Cantaure faunas as early as 1938 (González de Juana) and, despite Schilder's correlation with the Lower Miocene of Trinidad, Ingram (1947) described further fossil Cypraeidae from Cantaure which he considered of late Miocene age. Later still Jung (1965), in the most exhaustive study of the Cantaure fauna to date, tended to consider the assemblage as Upper-Middle Miocene despite recognizing several Lower Miocene forms.

Meanwhile, in the southern part of the peninsula, beds originally determined as Upper Miocene were reported as containing also Lower Miocene species (Rodríguez, 1968).

As a result of the general uncertainty as to exact age for these various Upper Tertiary levels there has been a continuing tendency to refer to the successions as "undifferentiated Tertiary".

During the course of several short visits to the Paraguaná Península prior to 1972 one of the writers (V.F.H.) collected samples for micropaleontological study from many of the shale and marl localities. From this material it became increasingly clear that at least two rich microfossiliferous horizons of differing ages were present which could prove to be effective time marker horizons for clarifying and differentiating the Upper Tertiary stratigraphy of the Península. One horizon was that of the Cantaure shell beds which consistently yielded a rich foraminiferal fauna with planktonic species indicating a Lower Miocene Globigerinatella insueta zone age; the other an equally rich level yielding excellent planktonic and benthonic foraminiferal assemblages belonging to the basal Pliocene Globorotalia margaritae zone. It was with this basic information that a survey was undertaken in 1972 to more clearly tabulate the Upper Tertiary sedimentary record of the Paraguaná Península.

LOWER MIOCENE

The Cantaure Formation

As indicated in the introductory section of this paper it has been the rich mollusc levels which have received most attention from geologists interested in the Tertiary geology of the Península. Only the publication of Jung (1965) gives any lithological descriptions, these being the informal unpublished notes of H. M. Bolli and R. M. Stainforth from letters addressed

to H. G. Kugler. Stainforth's notes are a precis of an unpublished 1956 Creole report by Brígido Natera which indicates that the Cantaure Formation was a term already in general use at that time by Creole geologists for Miocene sediments outcropping in the vicinity of Cantaure. The succession was stated as 75 meters thick and described as principally composed of "clays (60%) with sandstones and limestones of variable thickness and colour", overlapping "with strong unconformity on the igneous and Cretaceous rocks of the Mesa de Cocodite and conformably overlain by blanket limestones, etc., which cover most of the Península".

The Venezuelan Stratigraphic Lexicon of 1970 adopted Natera's Cantaure Formation as a valid stratigraphic unit but, as pointed out by Thomas and Macdonald (1970), the description of the type section was not that of Natera but the type locality of Ingram's mollusc faunas. A clarification and redescription of the type section of the Cantaure Formation is therefore needed as even Thomas and Macdonald do not appear clear as to the limits of the formation by describing two samples from what they believe to be the Cantaure Formation when only one of them falls within the stratigraphic limits of Natera's description.

The Cantaure Formation begins with a basal breccia largely composed of macerated shell fragments of Balanus. This is best exposed south-southeast of Casa Cantaure, in the Quebrada Barbasco, where it cuts back eastward across outcropping basement. Granite blocks of varying size are well displayed incorporated within the shell breccia which appears to be at least two meters thick.

Lack of continuous section and superficial slumping in the valley slope prevent detailed measuring of the complete section. Above the basal breccia the lower part of the formation, between the Quebrada Barbasco and Casa Cantaure, appears to be made up essentially of silty and gypsiferous shales with some sandy levels. The most distinctive feature of this part of the section is the rich mollusc levels, with the richest horizon outcropping approximately 500 meters south of the old Casa Cantaure and continuing eastward for almost one kilometer. This horizon includes the collecting localities of Weidenmayer, Hodson, Schilder, Ingram, and Renz (see Jung, 1965). Although faulting, superficial slumping, and hill wash affect the area the faunal variability at different outcrops suggest that more than one fossiliferous level is present.

The upper part of the Cantaure Formation is best exposed about one kilometer to the west of Casa Cantaure. Here the main fossiliferous horizon is succeeded above by shales alternating with thin limestones. The latter are mainly algal but contain mollusc levels with species in common with the underlying unconsolidated shell beds. The algal limestones cap Loma Barbasco, just south of Casa Cantaure, where algal balls up to two inches in diameter weather out and cover the slope of this hill. Approximately one kilometer to the west these limestones are replaced by jarositic and gypsiferous shales with macrofossil occurrences limited to a single horizon dominated by the large oyster Ostrea aff. aguaclarensis paraguanensis F. Hodson. At this point the whole of the upper part of the Cantaure Formation is represented by shale, and the section is capped by a limestone, the base of which marks the upper limit of the Cantaure formation as defined by Natera and adopted

here.

Natera estimated the total thickness of the Cantaure Formation to be approximately 75 meters. This appears to be a fair approximation.

Age of the Cantaure Formation

To date all published age determinations for this stratigraphic unit have been based on its rich mollusc faunas. Early workers (Hodson and Hodson, 1931, Senn, 1932, and Schilder, 1939) preferred a Lower Miocene age whilst later paleontologists (Ingram, 1949, Jung, 1965) have tended to correlate with younger Miocene units in the Caribbean area.

Hodson and Hodson (1931) simply state a Lower Miocene age for five mollusc species described from "Cantaure" but, according to an unpublished report by Senn (1932) "Dr. F. Hodson correlates it (the rich mollusc fauna of Cantaure) with the Cerro Pelado. The writer's opinion, which is based on an examination of quite rich collections, is that the Cantaure fauna has to be placed with the Lower Socorro (Querales shales)... I think that the Cantaure fauna shows us how the rich cast faunas of the Querales type locality would look if they could have preserved their shells". As the Querales shales are now considered as the upper part of the Cerro Pelado formation both Senn's and Hodson's determinations are not far apart.

Schilder (1939) supported Hodson's Lower Miocene age determination for the Cantaure shell beds by comparing fossil Cypraecea from the same locality with faunas from the St. Croix member of the Brasso Formation of Trinidad.

These initial Lower Miocene age determinations have never been popular with geologists familiar with the geology of the Paraguaná Península, probably mainly due to the more widespread occurrence of other obviously younger Tertiary fossil mollusc faunas throughout the Península. The outcrop of the Cantaure Formation is of very limited geographic extent and there has been a tendency to include it with the more widespread younger sediments because of lithological similarities.

Support for the latter interpretation appeared to be given by Ingram (1947) who described two new fossil Cypraeidae from the Cantaure beds which he considered indicative of a late Miocene age. Other geologists were in favour of a Middle or younger Miocene age as exemplified by Stainforth's precis of Natera's (1956) Creole report reproduced by Jung (1965). In this Natera concluded that the Cantaure Formation was "formerly called 'Cerro Pelado' but this is not acceptable because (1) lithologies are different, (2) it is impossible to trace one unit into the other, (3) faunas are different. He regarded the age as "early Middle Miocene" on molluscan evidence, but the fauna contains a surprising number of endemic species".

Jung (1965) also preferred a Middle Miocene age, finding more species in common with the Gatún Formation of Panamá and Costa Rica and the Cercado and Gurabo Formations of the Dominican Republic than with younger levels such as the Bowden of Jamaica, the Punta Gavilán of Venezuela, and the Springvale of Trinidad. However he did note similarities to the Lower Miocene Quiroz assemblage of the La Rosa Formation of the Maracaibo basin, listing 12 species

in common with the Cantaure level, but preferred to consider the Quiroz assemblage younger than then generally believed.

More recently Thomas and Macdonald (1970) collected two samples from what they believed to be two localities within the Cantaure Formation. One sample, from USGS locality 23888 (6.2 kms WNW of San José de Cocodite), was sent to Jung who identified the fauna and suggested a Middle Miocene age. The other sample, from USGS locality 23889 (3.6 kms WSW of Pueblo Nuevo), was sent to W.P. Woodring who indicated a middle to late Miocene age. Thomas and Macdonald finally chose to compare and correlate the Cantaure Formation lithologically and faunally with the Castilletes Formation (Middle Miocene) of the Guajira Peninsula.

Samples collected on several visits to the type locality of the Cantaure mollusc beds have consistently yielded rich foraminiferal faunas referrable to the Lower Miocene Globigerinatella insueta zone of Bolli (1957). Further sampling of the basal part of the overlying shale sequence has supported these conslusions by yielding even richer and well preserved foraminiferal faunas belonging to the succeeding Praeorbulina glomerosa zone. The good microfaunas were found associated with the mollusc levels and in the shales immediately overlying them. Within the shell beds the following planktonic foraminifera were identified:

Globigerinoides diminutus Bolli
Globigerinoides sacculifer (Brady)
Globigerinoides obliquus Bolli
Globigerinoides subquadratus Bronnimann
Globorotalia peripheronda Blow and Banner
Globigerina venezuelana Hedberg
Globoquadrina altispira (Cushman and Jarvis)
Globoquadrina dehiscens (Chapman, Parr, and Collins)

This fauna indicates a Lower Miocene (Burdigalian) age belonging to either the upper part of the Globigerinatella insueta zone of Bolli (1957) or the overlying Praeorbulina glomerosa zone (Bolli, 1966). The overlying shales contain also Praeorbulina glomerosa Blow and Orbulina suturalis Bronnimann, clearly indicating this level to belong to the Praeorbulina glomerosa zone.

An identical microfauna has now been indentified from the type section of the Querales shales, thereby confirming Hodson's mollusc correlation. Coincidently the richest foraminiferal assemblages were also found associated with the mollusc levels and shales immediately above them.

The foraminiferal evidence therefore supports the older determinations that the Cantaure Formation does correlate with Cerro Pelado Formation. It also correlates with the Jimol Formation of the Guajira Peninsula and not the younger Castilletes Formation as suggested by Thomas and Macdonald.

It is therefore suggested that:

a. a reinvestigation of the molluc faunas may indicate more species in common with Lower Miocene forms than previously anticipated. Jung listed 12 species in common with those occurring in the Lower Miocene Quiroz assemblage,

with this figured chart actually showing it to be 13. A 14th species occurs at another La Rosa locality which makes the total equal to the number of those in common with the supposed Middle Miocene Gatún Formation of Panamá. also, future studies may well prove several of the Caribbean and Central American units listed by Jung to be older than previously thought, rather than the Quiroz beds being younger, as suggested by that author.

b. The two samples collected by Thomas and Macdonald do not both come from the Cantaure Formation as defined by Natera and here adopted. The sample from locality USGS 23888 does indeed come from this level and the Middle Miocene determination by Jung is in accordance with his 1965 publication. That from locality USGS 23889 appears to come from the overlying limestone beds and was correctly identified as Middle or late Miocene by Woodring. The age of this limestone is discussed in a later section and is probably correlatable with the Castilletes Formation of the Guajira Peninsula. The Cantaure Formation is equivalent to the Lower Miocene Jimol Formation of that península.

P L I O C E N E

The Paraguaná Formation

Apart from the limited outcrop area of the Cantaure Formation at the southwestern end of the Mesa de Cocodite the greater part of the outcropping Tertiary sediments of the Paraguaná Península appear to be of Pliocene or younger age. These appear to belong to a simple and continuous sequence beginning with calcareous shales and ending with compact algal limestones, with an intermediate section composed principally of siltstones containning some limestone and sandstone levels. As sediments from this sequence cover the greater part of the surface of the Península it is proposed to define it as the Paraguaná Formation.

This sequence includes what Macdonald (1968) has loosely termed the "lutitas arcillosas de Punto Fijo", which he indicates as onlapping the Cantaure Formation and the metamorphic-igneous complex of the Mesa de Cocodite, correlating them with the Tertiary section exposed in the cliff sections of the western part of the Península. The latter sections, and their mollusc faunas have been described by Rodríguez (1968) who, however, considered the section as Miocene with both Upper and Lower Miocene time represented.

Rodríguez (1968) defined four sedimentary intervals in the cliff sections near Punta Cardón, Punto Fijo, and Judibana. The lowest of these intervals is represented essentially by unfossiliferous siltstones which he considered Lower Miocene in age based on the supposed fossil evidence of a Middle Miocene age for the succeeding calcareous interval (b). This determination appears mainly based on the identification of Ostrea gatunensis Brown and Pilsbury from the latter level. However, both field observations and the illustration in Rodríguez's paper indicate that the species belongs to Ostrea haitensis Sowerby, a stratigraphically younger species more indicative of uppermost Miocene or Pliocene age. Identification was kindly confirmed by Dr. P. J. Jung.

The authors have also found abundant specimens of Ostrea mesor Maury from the succeeding silty interval (c) which again tends to indicate a late Miocene or Pliocene age. This species probably corresponds to what has been described by Rodríguez as Ostrea of crassiformis Lamark.

This western coastal section in general lacks good marine clay horizons and therefore planktonic foraminifera are rare amongest the generally brackish to inner sublittoral assemblages. The richest levels are found associated with the calcareous interval (c) where, particularly in association with a bryozoan reefal development at Punta Cardón, the species Globigerinoides obliquus extremus Bolli and Bermúdez and Globorotalia pseudomiocenica Bolli have been found in rich foraminiferal and ostracod assemblages which also include the benthonic foraminiferal species Poroeponides repandus. This micropaleontological information indicates an age no older than Pliocene for the interval (c).

Even more conclusive evidence comes from the eastern part of the Península where a more marine section correlatable with the Punta Cardón, Punto Fijo, and Judibana sections, contains rich foraminiferal faunas of definite Pliocene age. Here the section is more conducive to a twofold lithological subdivision into a lower shale-siltstone interval and an upper limestone unit. It is believed that the basal marine shales of this section are most probably represented in the western part of the Península but not exposed and, for this reason, it is proposed that the type section for the Paraguaná Formation should be located in the east.

The proposed type section is located at Guaquira Arriba, 5 kilometers east of Pueblo Nuevo, on the road to Adícora, where it cuts through the scarp formed by these beds. The point is today marked by the location of two INOS water storage tanks located on the southern side of the road at the foot of the scarp. The best exposed section is immediately southeast of these tanks where a small quebrada, which crosses the road immediately west of the tanks, cuts back southeastward into the face of the scarp.

Here at Guaquira Arriba the section can be clearly subdivided into a lower shale-siltstone interval, here referred to as the El Hato member, and an upper limestone named here the Amuay member. The latter unit can be directly correlated with the interval (d) of Rodríguez (1968) in the western part of the Península.

The El Hato member is at least 30 meters thick based on the section measured at Guaquira Arriba but, although more completely exposed than in the western coastal sections, the base is still not exposed. The oldest sediment exposed is a homogeneous cream-coloured marine shale rich in foraminifera but rapidly grading upward into more silty beds, with the major part of the member becoming a banded sequence of grey siltstones alternating with thin ferruginous claystones and siltstones.

The overlying Amuay Member is a compact algal limestone identical to that capping the cliffs of the western coast of the Península where it is particularly well exposed at Amuay, due west of Judibana. The limestone is at least three meters thick and oftern capped by unconsolidated conglomerates which are probably of post-Pliocene age.

Age and Correlation

Rich foraminiferal faunas from the basal marine shale sections of the El Hato Member indicate that the Paraguaná Formation cannot be older than Pliocene age. The lowermost level exposed contains a rich microfauna including the following planktonic foraminifera.

Globorotalia margaritae Bolli and Bermúdez
Globorotalia miocenica Palmer
Globorotalia pseudomiocenica Bolli
Globorotalia acostaensis Blow
Globoquadrina altispira (Cushman and Jarvis)
Globigerina riveroae Bolli and Bermúdez
Globigerinoides ruber (D'Orbigny)
Globigerinoides conglobatus (Brady)
Globigerinoides obliquus extremus Bolli and Bermúdez
Globigerinoides trilobus (Reuss)
Globigerinoides sacculiferus (Brady)
Pulleniatina primalis Banner and Blow
Sphaeroidinella dehiscens (Parker and Jones)
Hastigerina aequilateralis (Brady)
Orbulina universa D'Orbigny

This fauna represents the Globorotalia margaritae zone of Bolli and Bermúdez (1965) and indicates a Lower Pliocene age. A similar assemblage can be found in other clay exposures beginning 3 kms due north of Pueblo Nuevo on the road to El Vínculo. The member is particularly well exposed in Cerro El Pelón.

The mollusc faunas of the type section are also correlatable with those on the west coast of the peninsula. Ostrea haitensis is followed upward by Ostrea mesor suggesting that the El Hato Member is equivalent to the (a), (b), and (c) intervals of Rodríguez on the west coast. Ostrea mesor is particularly common throughout the Península wherever the El Hato Member is exposed.

Locally an orange-coloured ferruginous calcareous sandstone containing a rich planktonic foraminiferal fauna is found toward the top of the El Hato Member in the eastern part of the Península. This may correlate with the calcareous interval (b) of Rodríguez in the west.

The microfaunas of the Paraguaná Formation indicate correlation with the Cubagua Formation of the Araya Península and the island of Margarita, and the La Vela Formation of Central and Eastern Falcón.

MIDDLE-UPPER MIOCENE

The recognition and definition of two clearly time-separated sequences within the previously undifferentiated Upper Tertiary of the Paraguaná Península leads to the problem of determining whether the intervening geologic time (Middle and Upper Miocene) is also represented in the sedimentary record. No direct paleontological evidence has yet been found to suggest that there has been continuous sedimentation from Lower Miocene to Pliocene time but

there are a few anomalous lithological units which could well fit into this time interval.

The limestone capping the Cantaure Formation west of Casa Cantaure is one such unit which could be fitted into this Middle-Upper Miocene time interval as it appears conformable on the upper shale section of the Cantaure Formation. However, Natera (in Jung, 1965) suggests that this "blanket limestone" correlates with those "which cover most of the Península (probably Middle to Upper Miocene)". However, it is now clear that the latter limestones are Pliocene in age and that a considerable time break must exist between the Cantaure and the overlying limestone if Natera's assumptions are correct. Either the limestone is in fact unconformable (or at least disconformable) on the Cantaure Formation or the limestone must belong to post-Cantaure and pre-Pliocene time. The latter interpretation is presently favored as the limestone appears conformable and has certain facies characteristics, particularly with regard to algal growth forms, which are not found outside the Cantaure area. The limestone capping Loma Barbasco immediately south of Casa Cantaure, clearly correlates with that capping the southern slope of the Quebrada Barbasco, dipping southward into the Las Clavellinas syncline (see map of Feo-Codecido, 1971). The dominantly limestone sequence outcropping in this synclinal area south of the Mesa de Cocodite area may well prove to be Middle to Upper Miocene in age. Macsotay (1971) correlates Turritella faunas of limestones at "Cerro La Idea, southwest of Casa Cantaure" with similar faunas at the top of the Socorro Formation and the base of the Caujarao Formation (Middle-Upper Miocene) of Central Falcón. Also, USGS locality 23889 probably belongs to this limestone level, the molluscs of which have been determined as Middle or Late Miocene by Woodring (see Thomas and Macdonald, 1970).

Another lithological unit which may well prove to also belong to the Middle-Upper Miocene time interval is a dark red-brown ferruginous sandstone outcropping at the eastern end of the Mesa de Cocodite area. This sandstone occupies a narrow north-south strip about a half kilometer wide bounded to the west by the metamorphics of the Pueblo Nuevo Formation and on the east by white Pliocene limestones. The contacts are most probably faulted. The sandstone is mainly composed of ellipsoidal haematitic pellets which were probably originally glauconitic or chamositic, and the remaining faunal evidence is limited to a few ferruginous molds which suggest a middle Miocene age.

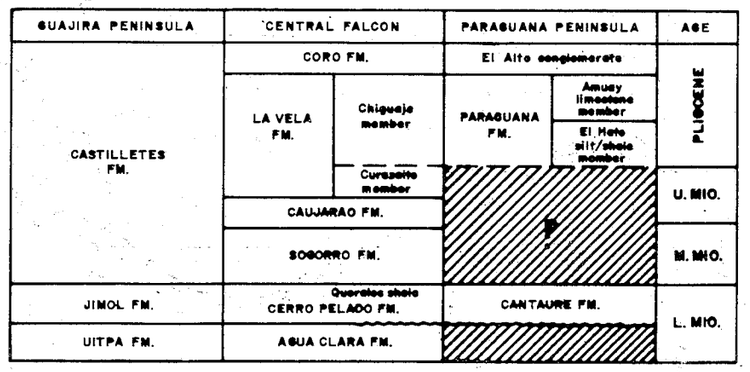
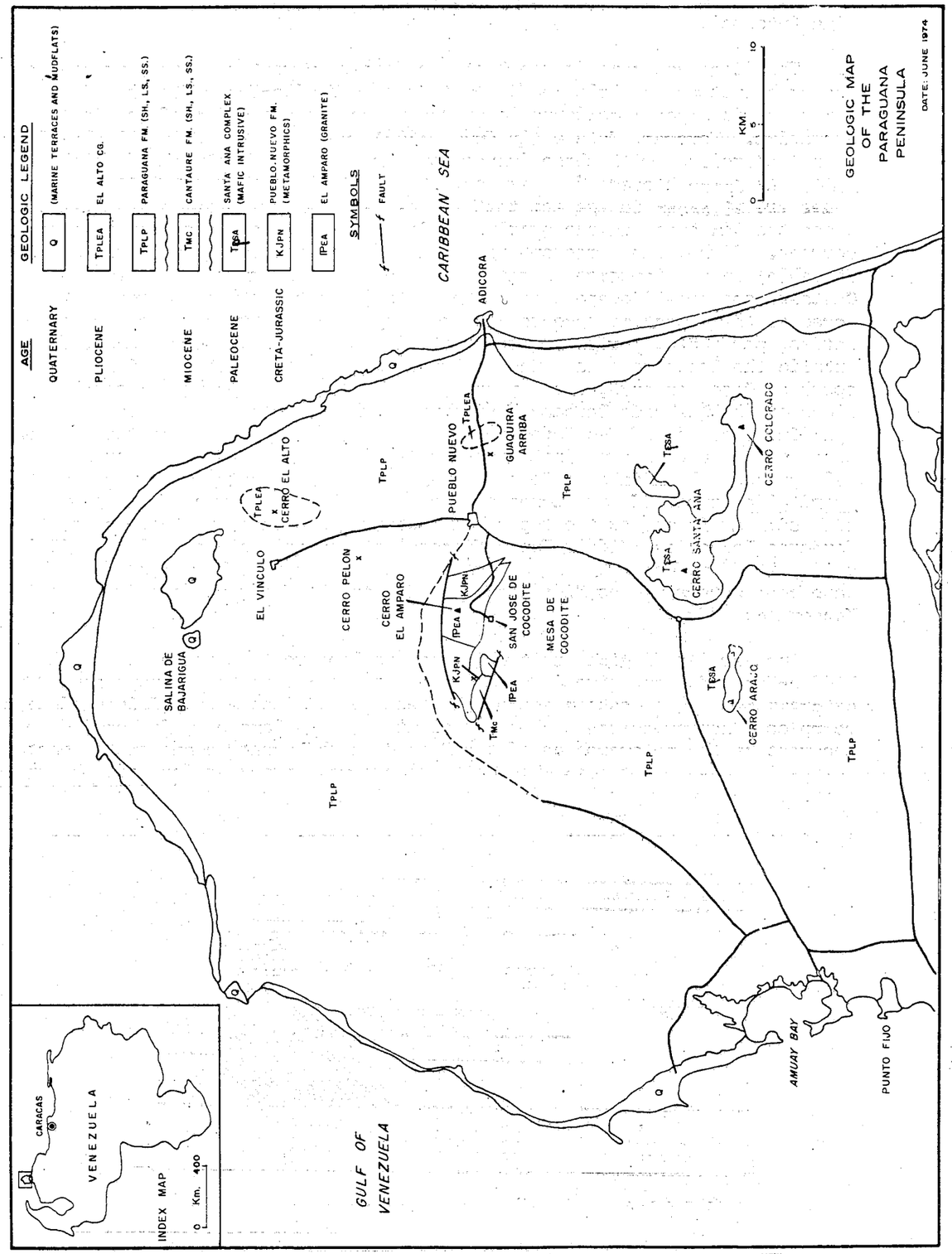


Tabla de correlación.



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NOTAS GEOLOGICAS

GEOLOGICA Y PETROLOGIA DE LA REGION DE PUERTO AYACUCHO, TERRITORIO FEDERAL AMAZONAS[1]

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R E S U M E N

En el presente trabajo se estudia la geología de la región de Puerto Ayacucho. La atención se concentró en las rocas ígneas que afloran en el área, ya que los otros tipos de rocas presentes están constituídas por los aluviones y suelos, éstos en su mayoría residuales originados a partir de las rocas ígneas ácidas.

Las rocas ígneas del área forman parte de un gran batolito de unos 280 x 150 km, constituído por rocas ígneas ácidas, de composición granítica, altamente feldespática, predominando el feldespato potásico, con un alto contenido de fluorita, y que se caracterizan por presentar la típica textura rapakivi, denominado Granito de Parguaza.

Es un batolito de origen magmático, siendo el magma original rico en K y volatiles, cristalizado a altas presiones de agua, y a diferentes profundidades, emplazado en la epizona y orogenéticamente post-tectónico. Presenta pequeños cuerpos de granito de grano fino originado por cristalización de líquidos residuales del mismo magma, y de granito de aspecto moteado producto posiblemente de la asimilación de rocas cuarzosas estratificadas.

La edad asignada al Granito de Parguaza es de alrededor de los 1.500 m. a. determinada a partir de roca total por Rb/Sr y U/Pb por Hurley y Gaudette. Presenta xenolitos de rocas que pudieran pertenecer a la Formación Cinaruco y de otras gneisicas no bien ubicadas. También se localizó un pequeño cuerpo de charnokita.

El área estudiada estructuralmente es simple y solo se observaron diaclasas

[1] Resumen de un trabajo especial de grado, presentado al Departamento de Geología de la Universidad Central de Venezuela para optar al título de Geólogo. El Trabajo completo puede consultarse en las bibliotecas de la U.C.V.

[2] División de Investigación Aplicada, CODESUR-MOP, Caracas.