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TECTONICS, PALINSPASTIC BASE MAPS, AND PALAEOGEOGRAPHY

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CONTENTS OF CD-ROM

A. All maps, figures, texts of this atlas, PDF and CANVAS format
B. Measured sections and environmental assessments, Serrania del Interior Oriental
C. Expanded texts and figures of complementary material, including expanded discussion of stratigraphic sections in east and west Venezuela, new biostratigraphic dating and bibliography.
THE STRATIGRAPHIC DEVELOPMENT OF THE PASSIVE MARGIN

The Cretaceous stratigraphy of Venezuela shows a regional transgression, starting at the end of the Jurassic and reaching its maximum in the Early Turonian (Phanerozoic MFS). This was followed by a regional regression that continued into the Cretaceous. In western Venezuela, with a latest Cretaceous (Maestrichtian-Paleocene) transgressive pulse only in eastern Venezuela. This first-order sequence filled accommodation space created by relatively local Tassie to Barremian extension followed by regional thermal subsidence on which eustatic sea-level changes were. The record of this can be easily divided into second-order and in some cases into third-order sequences. The use of sequence stratigraphic nomenclature here does not imply an interpretation concerning eustasy but is only descriptive, based on evidence from extensive field work, sedimentological and palaeontological analyses, all plotted on re-tro-deformed base-maps to produce the palaeogeographic maps in this atlas.

Cretaceous time slices presented in this report were selected in an unconventional manner. We have not selected the traditional stage-by-stage approach for the construction of the maps nor have we divided the Cretaceous into time slices of equal duration. Instead, our division of the Cretaceous system is based on facies associations which can be grouped into sequences and related depositional systems rather than forced into specific time periods. In several cases, facies or ages shown on the maps do not match the published literature for many reasons including:

- Poor dating and inadequate stratigraphic philosophies yield different names for the same unit and the same name applied to different units, both of which lead to maps full of spurious and unrelated detail, or artificial grouping of units which may be separated by one or more transgressive/regressive cycles. The maps presented here have taken care to avoid stratigraphic nomenclatural problems and if we propose to put two formations in the same map it is because we have our own direct observational evidence rather than assemblages of information from the literature.
- Different names for slightly different facies within different basins and nomenclatural complications introduced by "competing" companies, surveys and universities. Why, for example, do names change from the east to the west of Venezuela or from one side to the other of the Mérida Andes? Questions such as which unit is equivalent to the La Luna or what is the age of the Capacho become common and difficult to resolve without an adequate biostratigraphic framework. The maps presented here are viable hypotheses created with a biostratigraphic framework and with sequence stratigraphic concepts and methods.
- Many different names for completely different facies. In terms of traditional stratigraphy it is extremely common to propose different names for facies that are different and of the same age (coeval and heteropic) but this complicates understanding regional distribution and significance of these facies changes. A clear example is the relationship between the Escaladaosa Formation of the Barinas Basin, and the coeval Seboruco and La Grita members of the Capacho Formation near Mérida.

In addition to nomenclatural problems mentioned above, eastern and western Venezuela stratigraphy has been treated as completely different because those two regions are currently separated by a metamorphic belt. The two are more similar than normally usually thought but their connection gets complicated by poor biostratigraphic constraints in shallow-water facies and by differences in stratigraphic thickness. Furthermore, there are many more stratigraphic nomenclatural problems which are related to the intrinsic nature of some geologists and their need for duplicating simple explanations proposing new names. The maps presented and described in this report were constructed with all these issues and constraints in mind. They follow sequence stratigraphic concepts and methods. However, all the maps comprise a time interval rather than a time line and may represent several depositional sequences which were deposited in a general trend without major breaks in deposition. For this reason the maps contain a mixture of facies of slightly different ages and should be read bearing this in mind. The maps are accompanied by detailed sequence stratigraphic cross sections for the map time interval, resuscitating correlatability of facies with better time precision and we also provide summary stratigraphic cross sections (Page 5b) showing our views on Cretaceous sea-level behaviour and basin filling.

CRETACEOUS STRATIGRAPHY

Facies boundaries presented in the maps commonly improve upon facies and ages compiled from our literature search; consequently, map descriptions are only partially based on literature. Descriptions presented here contain alternative hypotheses and ideas, many of which have been tested whereas others remain untested. Another issue concerns the thickness of the Cretaceous, both the total thickness and the thickness of individual Cretaceous stages and/or formations. Thicknesses have been grossly overestimated in some regions due to non-recognition of low-angle faults, largely because many classic studies pre-date the awareness of the importance of large-scale horizontal displacements.

We need to re-stress the importance of the palimpsestic reconstruction of the Andean orogeny on which the Cretaceous facies and units have been plotted. Variable amounts and directions of shortening of up to 200 km and huge strike slip offsets have occurred across and within the Andes, depending on location. Acknowledgment of these displacements is essential to the proper interpretation of the original size and configuration of the Cretaceous depositional platform and data plotting in this palaeo-reference frame allows a more accurate portrayal of facies relationships, of the platformal character of the Cretaceous, and of the parameters controlling hydrogen source rock quality. Also critical is the description of the size and shape of the early foredeep basins along the leading edge of the early Andes - the area covered by viable source rocks was initially far larger than their present distribution and areas of early maturation and the distances over which oil migration has taken place can only be appreciated by developing the palaeogeography in the palinspastic framework. In the descriptions of the various maps which follow, basinward or landward movement of this facies boundary is, by definition, transgression or regression, respectively. Transgression and regression are shown almost independently of shifts in coastal onlap, as sequence stratigraphic theory proposes. In most maps there is an arrow or a series of arrows that represent what that facies boundary lines were doing for the particular map interval.

CRETACEOUS STRATIGRAPHIC CHART

Showing ages used in this study and published ages, for comparison. Most discrepancies in age are related to a lack of ammonite data. Our revised ages incorporate new data on microfossils (plant/foraminifera) and bivalves where needed. Of particular note are some of the correlations between eastern and western Venezuela: correlation of the Rio Negro/Tibu with Barraquín carbonates/clastics; Guaimaros, Machiques and Garcia Fir shales belonging to the same transgressive sequence tract; the Aguardiente/Lasure/Peñas Altas with the El Cantil/Chimana; the very widespread distribution of Alban to early Campanian shales of the La Luna, Querecual, San Antonio, Colon Fms. Note also the more abrupt and earlier Cretaceous regression in western Venezuela. The revisions allow us to construct sensible and internally consistent sequence stratigraphic cross-sections.

KEY TO FACIES ON STRATIGRAPHIC CHART

- Sols dominate; fluvial or shallow marine
- Shales dominate; generally marine
- Chert or highly siliceous shale
- Marine shales/claystones, non-calcareous
- Calcareous shales, organic rich, generally associated with hemipelagic foramin-fosi
- Calcitic carbonate concentrations
- Condensed deposits, phosphatic and glauconitic
In the west facies of the Río Negro have relatively distal equivalents (referred as mal subsidence, locally favouring the development of shallower-water belts well away from the Guyana Craton and resulting in development of additional shallow-water facies belts away from the paleocoastline.

Facies associations for this time interval show the effect of differential post-rift ther-
clastics mixed with carbonate buildups and localized reefs with little shale and fewsource rocks (Caqueza Gp in East. Cord. of Colombia is an exception, due to greater

The Early Cretaceous transgression is generally composed of shallow-water silici-
clastics mixed with carbonate buildups and localized reefs with little shale and fewsource rocks (Caqueza Gp in East. Cord. of Colombia is an exception, due to greater

In terms of sequence stratigraphy, the Early Cretaceous can be generally assigned to a transgressive systems tract with several regressive episodes. Transgressive-regressive episodes as well as the general transgression that occurred during this time interval are shown in the map as a wavy line with an arrow at the end. Direc-
tional of the line implies time with the initial portion of the arrow being at the base of the time span comprised in the map and the tip of the arrow at the end of the time comprised on the map.
LATE OLIGOCENE PALAEOGEOGRAPHY

From Late Oligocene time, continuing oblique collision was accompanied by the onset of the Andean Orogeny and the onset of E-W trending transcurrent faulting along northern South America, which eventually involved the Falcón Basin. Continued eastward migration of the Caribbean Plate required E-W trending dextral faults to propagate through the allochthons (once part of the Caribbean Plate) once they ‘docked’ against northern South America. The eastward propagation of overthrusting, then docking, implies that strike-slip and associated basins also younged east - with present day propagation occurring in easternmost Venezuela and Trinidad. In the Falcón area, dextral slip may have been incipient at this time (onset of E-W trending transcurrent faulting on 13b). Enhancement of Falcón subsidence and northern Maracaibo rebound (see inset above). Most of the rebound had occurred by the latest Oligocene or earliest Miocene, prior to deposition of the Icocta Fm. The eroded area was then transgressed by the La Rosa Formation sea in the Early Miocene, driven by load-induced subsidence related to Andean thrusting. By now, the leading edge of subducted Caribbean lithosphere had reached to beneath eastern Lake Maracaibo, requiring underthrusting along the north side of the Leeward Antilles, at this time located just north of Falcón. This ‘trench’ must also have propagated eastwards with the leading tip a scissors type fault zone (see inset on Page 13a) with the Leeward islands forming a large wedge, with likely very complex internal deformation, overlying oppositely-dipping underthrust zones. At about this time, arc volcanism began in the southern Lesser Antilles and extension in Grenada Basin slowed.

A dramatic increase in rate of westward advance of South America over the mantle at ca. 25 Ma seems to have kick-started Andean orogeny in the west, with the tec-tic load of the rising Perú–Andes and Santander Massif driving the depression filled by “Lake León” in the Maracaibo area, which was filled by onlapping coarse sediments prograding from west (Peroc Fm) and NE (Palmar Fm). Explicit evidence for Merida Andes uplift is less clear. Chert pebbles in the basal Guayabo Fm might have come from the Santander Massif. 21-24 Ma AFT ages are known only from the Valera Granite (?local Bocono Fault...). In the early Miocene, emergence of the prism provided detritus for the Nar-icual Fm of the western Serranía.
<table>
<thead>
<tr>
<th>Time</th>
<th>Setting/Stage</th>
<th>Stratigraphy</th>
<th>Source</th>
<th>Reservoir</th>
<th>Seal</th>
<th>Traps</th>
<th>Matur'n</th>
<th>Migration history</th>
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<tr>
<td>Quaternary</td>
<td>Accelerating uplift of Mérida Andes, part of load directed toward Barinas Basin, with up to 5 km foredeep fill (thermal blanket).</td>
<td>Guanapa, Rio Yuca, Parangula, (Quebradon)</td>
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<td>E-ward and S-ward migration from sub-thrusted in Andes. Foredeep fill is generally not deep enough for intra-basinal maturation.</td>
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<tr>
<td>Pliocene</td>
<td>Rebound of Lara foredeep causes regression, erosion</td>
<td>Unconformity and hiatus</td>
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<tr>
<td>Miocene</td>
<td>Distal foreland basin (of Lara nappes, northern Maracaibo)</td>
<td>Unconformity and hiatus</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td>Possible arrival of oil from northern Maracaibo (Lara) foredeep (Pauji/Paguey time). Oils would have been biodegraded immediately, due to lack of burial in the Barinas Basin.</td>
</tr>
<tr>
<td>Oligocene</td>
<td>Passage of peripheral bulge. Block faulting, erosion down to Turonian on horsts.</td>
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**Basin:** BARINAS

Two Orocué Groups (Los Cuervos Fm) and Mirador Fm, Tarra Anticline.

Type area of the Mirador Fm ssts. Underlain by mudstones of the Los Cuervos Formation (Orocué Gp). Lower units of the Orocué, i.e. Catatumbo, Barco Fms are not exposed here. Nearby, a large oil seep occurs in Orocué Gp sandstones.

Age: Los Cuervos Fm is Paleocene and the Mirador is lower and middle Eocene, but palynological dating is not particularly good in this area.

Facies description: Lower 50 m consists of Los Cuervos gray and mottled gray-pink, massive mudstones with some rootlet levels, with a 6 m cross-stratified sandstone, with bioturbated upper surface. Nearby there are coal beds lower down. Mirador is mostly fine-medium sst. Sst up to 15 m thick are separated by 1 m pale gray, structureless mudstones. Lowest sst has an incised base, with ca. 7 m relief over 40 m laterally with basal 1 to 2 m coarse grained and oil stained.

Facies interpretation: Los Cuervos mudstones interpreted as aggradational palaeosols formed in a fluvial- or delta plain overbank setting. The associated sandstone interpreted as a fluvial (more likely given distance from the rift) or distributary channel. Orocué sandstones interpreted as fluvial deposits, in association with overbank-paleosol mudstones. With evidence for lateral accretion elsewhere this implies a meandering, rather then braided, stream setting. The incised base of the Mirador, combined with regional thickness variations suggests it fills incised valleys, implying an unconformable contact with the Los Cuervos. Palynology shows no detectable time gap, suggesting the relative sea-level fall was of short duration, possibly corresponding to one of the three Type-1 sequence boundaries clustered near the Paleocene-Eocene boundary on the Haq et al. (1988) chart.

3) Orocué Gp (Catatumbo, Barco, Los Cuervos fms), Río Lobaterita canyon. (Logs above right)

Entirely within the Orocué Gp comprises mudstone-rich intervals at the base and top, separated by a 50 m sandstone-dominated unit, consistent (both lithology and thickness), with the tripartite Orocué Gp regional stratigraphy.

Age: Fossils are rare in the Orocué Group. Most palynological data suggests it is Paleocene. On our paleogeographic maps, we assume the Catatumbo Formation to be Lower Paleocene and the Los Cuervos Formation to be Upper Paleocene (Pages 10B, 11A).

Facies description: Lower 30 m are dark gray mudstones, succeeded by 50 m of pale gray and mottled gray-pink, massive mudstones with rootlets and coal beds. The associated sandstone of the Los Cuervos Formation (Orocué Gp) can be assigned to the Los Cuervos Fm. We assign only the lower two of the three sands to the Mirador Fm. The “third sand”, plus the underlying heterolithic interval (206-215 m) probably belong to the Carbonera Fm with a basal transgressive lag and a different depositional environment. This unconformity (at 205 m) at the base of the Carbonera Fm is noted regionally.

Age: The Carbonera Fm “third sand” is late Middle or Late Eocene age, coeval with the main reservoir at Guáitita and Canón Limon, all probably similar tide-influenced delta deposits. Third sand section could be a useful outcrop analog for reservoir-modeling studies. The upper mudstone-dominated interval (280-300 m) gave palyno-ages of Early Eocene and Late Paleocene-Early Eocene, suggesting a repetition of the Orocué Gp by a fault, with associated breccia.

Facies description: The Los Cuervos Fm (0-160 m) is dominated by variably colored mudstones with rootlets, coal interbeds and crocodile remains. The “first sand” and “second sand” (Mirador Fm) are sharp-based, trough cross-stratified, fine-sand with coarse sand/pebbles common in the lower 2 m of the “second sand” (quartzite and chert), with no burrows. Capping the “second sand” is a thin (1-1.5 m) trough-cross-stratified bed whose foresets alternate between fine sandstone and conglomerate (base of Carbonera), with some tabular mudclasts up to 40 cm long. The base of the bed undulates irregularly; the top has symmetrical ripples. Overlying is a coarsening-upward succession, starting with burrow-mottled mudstone, followed by 7 m of heterolithics and topped by the tabular cross-bedded channel-filling “third sand” (part of Carbonera Fm). Above 243 m, probably faulted Los Cuervos, is dominated by: (1) burrow-mottled mudstones; and (2) heterolithics, slightly burrowed facies. Roolsets are present in a 10 cm mudstone bed at 285 m. Thin coal beds are noted at 284 m and at 300 m.

Facies interpretation: The Los Cuervos (0-160 m) was deposited in a mud-dominated alluvial or delta floodplain environment prone to emergence (rootlets and crocodile remains). The base of the Los Cuervos is interpreted as offshore-lacustrine deposits. Asymmetrical-ripple marks represent dilute, river-fed turbidity currents, common in lakes. The mud-dominated discordance at 133 m is interpreted as a slide or slump scar. In contrast, the channelized discordance at 145 m is interpreted as a non-depositing channel, filled passively after abandonment by onlapping strata, including a basal slump bed. The succeeding upward-convex packages are interpreted as channel- and bedload-fed, possibly dispersed depositional lobes, again found in lakes. The combination all suggests a lacustrine delta-front environment. The mudstones capping the section may be paleosols, interpreted as floodplain deposits, consistent with the overall fluvial and/or deltaic Orocué interpretation here.
Reference Section for Los Jabilos Fm, Río Querecal.

1.5 sandstone, moderately well sorted very fine-grained, with mineral grains in solved, rounded near top (except for a couple of large boulders), massive, oil stained, carbonaceous, thick bedded, medium grey.

2. quartz arenite, very fine-grained, sorted, medium bedded with some horizontal lamination, darker upper part, light grey, medium grey.

3. sandstone, fine-grained and silt laminated; harder upsection (more cement less oil); 78.5 m on column. 5.5 quartz arenite, fine-grained, pale white and rust; very hard; thick medium bedded; mostly medium grey, locally horizonally laminated with very coarse-angle cross-lamins and first suggestion of ripples. 30 m up column.

4. sandstone, poorly sorted (very fine-grained); oil-stained grey, poorly cemented; thinly laminated, sharp contact.

5. quartz arenite, fine-grained, pale white and rust; very hard; thick medium bedded; mostly medium grey, locally horizonally laminated with very coarse-angle cross-lamins and first suggestion of ripples. 30 m up column.

6. sandstone, fine to medium grained, medium bedded; horizontal laminations, white, mostly or horizontally laminated with fine to very fine grained sand. 49.5 m on column.

7. sandstone, fine to medium grained, medium bedded; horizontal and cross laminations in places, pale grey, hard, medium grey, medium grey, sharp contact, very hard, massive, massive, yellow to grey, sharp contact, very hard, massive, yellow to grey, sharp contact. 44 m on column. 2.5 sandstone, horizontal laminations, white, mostly or horizontally laminated with fine to very fine grained sand. 49.5 m on column.

8. sandstone, moderately well sorted very fine-grained, with mineral grains in solved, rounded near top (except for a couple of large boulders), massive, oil stained, carbonaceous, thick bedded, medium grey.

9. sandstone, fine to medium grained, medium bedded; horizontal and cross laminations in places, pale grey, hard, medium grey, medium grey, sharp contact, very hard, massive, yellow to grey, sharp contact, very hard, massive, yellow to grey, sharp contact. 44 m on column. 2.5 sandstone, horizontal laminations, white, mostly or horizontally laminated with fine to very fine grained sand. 49.5 m on column.

10. sandstone, fine to medium grained, medium bedded; horizontal and cross laminations in places, pale grey, hard, medium grey, medium grey, sharp contact, very hard, massive, yellow to grey, sharp contact, very hard, massive, yellow to grey, sharp contact. 44 m on column. 2.5 sandstone, horizontal laminations, white, mostly or horizontally laminated with fine to very fine grained sand. 49.5 m on column.

11. sandstone, moderately well sorted very fine-grained, with mineral grains in solved, rounded near top (except for a couple of large boulders), massive, oil stained, carbonaceous, thick bedded, medium grey.

12. sandstone, fine to medium grained, medium bedded; horizontal and cross laminations in places, pale grey, hard, medium grey, medium grey, sharp contact, very hard, massive, yellow to grey, sharp contact, very hard, massive, yellow to grey, sharp contact. 44 m on column. 2.5 sandstone, horizontal laminations, white, mostly or horizontally laminated with fine to very fine grained sand. 49.5 m on column.

13. sandstone, moderately well sorted very fine-grained, with mineral grains in solved, rounded near top (except for a couple of large boulders), massive, oil stained, carbonaceous, thick bedded, medium grey.

14. sandstone, fine to medium grained, medium bedded; horizontal and cross laminations in places, pale grey, hard, medium grey, medium grey, sharp contact, very hard, massive, yellow to grey, sharp contact, very hard, massive, yellow to grey, sharp contact. 44 m on column. 2.5 sandstone, horizontal laminations, white, mostly or horizontally laminated with fine to very fine grained sand. 49.5 m on column.

15. sandstone, moderately well sorted very fine-grained, with mineral grains in solved, rounded near top (except for a couple of large boulders), massive, oil stained, carbonaceous, thick bedded, medium grey.

16. sandstone, fine to medium grained, medium bedded; horizontal and cross laminations in places, pale grey, hard, medium grey, medium grey, sharp contact, very hard, massive, yellow to grey, sharp contact, very hard, massive, yellow to grey, sharp contact. 44 m on column. 2.5 sandstone, horizontal laminations, white, mostly or horizontally laminated with fine to very fine grained sand. 49.5 m on column.

17. sandstone, moderately well sorted very fine-grained, with mineral grains in solved, rounded near top (except for a couple of large boulders), massive, oil stained, carbonaceous, thick bedded, medium grey.

18. sandstone, fine to medium grained, medium bedded; horizontal and cross laminations in places, pale grey, hard, medium grey, medium grey, sharp contact, very hard, massive, yellow to grey, sharp contact, very hard, massive, yellow to grey, sharp contact. 44 m on column. 2.5 sandstone, horizontal laminations, white, mostly or horizontally laminated with fine to very fine grained sand. 49.5 m on column.
Extras on Venezuela Exploration Framework Atlas CD-ROM:

**MARA_LGS.pdf**
Maracaibo area logs - full description, locality details, bibliography - complements logs in atlas

**PALYAGES.pdf**
Our new palynological age data for the Maracaibo area

**EAST_LGS.pdf**
Selected Serrania area logs (our field studies) - full description, locality details, bibliography - complements logs in atlas (11 pages)

**VEN_PET.pdf,cwk**
pdf and Clarisworks versions of our sandstone petrography database (164 samples)

**SERRANIA.pdf**
Text and figures for our reworking of Ministry logs for Serrania (133 pages)

**CRT_LGS1.PDF**
Ca. 1 cm = 10 m logs, Wide format (915 mm) pages with our annotation, revised correlations, new stratigraphic ages, facies interpretation for Cerro El Paraiso, Isla Chimana Grande (West), Isla Venados, Peninsula Pertigalete (West), La Puerta, Quebrada Güirintal, Quebrada Los Altos, Quebrada Rincon, Rio Caripe (S.W.), Rio Perdido, Rio Capiricual

**CRT_LGS2.PDF**
Alto El Zamuro, Cerro Canton, Cerro Copei, Cerro La Paloma, Isla Chimana Grande (E), Isla Picuda Grande

**CRT_LGS3.PDF**
N.E. de Tacata, Quebrada Los Chorros-Rio La Maravilla, Rio Caripe (S.E.) Rio Querecual, Rio Triste-Quebrada Rincon, Valle grande-Las Chaguaramas, Valle grande-Trapiche Santa Rosa

**TER_LGS1.pdf**
Cerro Canton, Cerro Limon-Cuspural, El Banco, Quebrada Teresen, Rio Colorado

**TER_LGS2.pdf**
Alto La Paloma, Cerro Los Caballos, Quebrada La Salada, Rio Aragua (East), Rio Aragua (West), Rio Punceres, Sinclinal de Tinajitas (North), Sinclinal de Tinajitas (South)

**TER_LGS3.pdf**
Cerro Los Godos, Quebrada Pegua, Rio Amana-Rio Oculto, Rio De Oro (North), Rio De Oro (South), Rio Oregano, Rio Capiricual Este, Rio Guarlo

**BIBLIO.txt**
Text only version of bibliography (3826 entries)

**Ven_biblio_95**
Endnote bibliography for Venezuela, up to 1995
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**Stratigraphic unit:** "El Tambor Sandstones"

**Location:** Quarry, road to La Azulita

**Lithology:** quartz arenite

**Age:** E - M Eocene

**Country:** VE

**Latitude:**

**Longitude:**

**UTM:** N&S

**E&W**

**Maturity:** m

**Sand to shale ratio:** 99:1

**Grain size:** mean: 2 minimum 4 maximum 2

**Sorting:** vws

**Grain relationships:** ccc, lc, gs

**Roundness:** r

**Porosity:**

**Diagenetic characteristics:** euhedral quartz overgrowths and solution

**Major minerals:** quartz

**Minor minerals:** K-feldspar, heavy minerals

**Point count data:** n: 226
- Monocrystalline quartz: 212
- Polycrystalline quartz: 4
- K-feldspar: 4
- Plagioclase: 0
- Lithic fragments: volcanic: 0 sedimentary: 0 metamorphic: 0 chert: 0
- Phyllosilicates: 0
- Dense minerals: 2
carbonates: 0 other: 0
- Cement: calcite: 0 chlorite: 0 silicate: 0 other cement: 4

**Cement:** hematite, quartz overgrowths

**QFL percent Q:** 98.2
**QFL percent F:** 1.8
**QFL percent L:** 0.0
**Pto F:** 0.0
**Lsm:** 0.0
**Lvm:** 0.0

**Minor minerals:**
- K-feldspar: 4
- Plagioclase: 0
- Lithic fragments: volcanic: 0 sedimentary: 0 metamorphic: 0 chert: 0
- Phyllosilicates: 0
- Dense minerals: 2
carbonates: 0 other: 0
- Cement: calcite: 0 chlorite: 0 silicate: 0 other cement: 4

**Comments:** many heavy minerals, no porosity, quartz overgrowths

**Outcrop Data**

**Exposure type:**

**Unit thickness:**

**Thickness accuracy:**

**Depth of sample:**

**Strike:**

**Dip:**

**Depth accuracy:**

**Contacts:** upper lower

**Depositional environment:**

**Bedding:**

**Grading:**

**Paleocurrent:**

**Color:**

**Weathering:**

**Oil staining:**

**Tectonism:**

**Paleobathymetry:**

**Comments:** collected by Roger Higgs.