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GEOLOGY AND URANIUM POTENTIAL OF THE GONDWAMA SEDIMENTS IN THE NORTHEASTERN PART OF THE CONCESSION AREA

By: D.S. Hutchison May, 1980

SEDIMENTS IN THE NORTHEASTERN PART OF THE CONCESSION AREA by; DSH-May 1980

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C O N T E N T S

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C O N T E N T S (Contd'd.)

SUMMARY

The geology and uranium potential of the Gondwana sediments in the northeastern part of the concession area are described.

Broadly, the geological sequence in the area can be divided into the following groups:

(a) Alkaline complexes and their marginal up-domed pre-Gondwana host rocks.

(b) Gondwana sediments and volcanics.

(c) Surficial deposits.

The Gondwana series consists of a basal sequence of glacial diamictites (LPC) overlain by a series of thickly bedded to massive sandstone units. These, in turn, are overlain by continental flood basalts.

The lowermost of the massive sandstone units contains intercalated beds of LPC diamictite and is interpreted to be probably UPC in age. The upper sandstone units form a distinctive escarpment-mesa-butte landscape and are interpreted to be Mesozoic in age. Interbedded basalt flows are present at the top of this sequence, and, in the vicinity of the Cerro Sarambí and Chirigüelo alkaline complexes, a highly conglomeratic sandstone member (consisting of a high proportion of conglomerate and fanglomerate derived from the complexes) has been mapped as a separate unit.

Small areas of alternating siltstone, mudstone, and sandstone of UPC age are exposed in the southern part of the area.

The UPC massive sandstone and alternating sequences are the only sedimentary units in the area considered to have significant uranium potential.

It is recommended that the first phase of follow-up exploration in these units should consist of reconnaissance core drilling, based wherever possible on the results of the 1980 detailed airborne radiometric survey.

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INTRODUCTION

This report describes the geology, stratigraphy, and uranium potential of the sedimentary units in the northeastern part of the concession area (north of 23° and east of the Apa High, Fig. 1). The alkaline complexes present in the area are not described in detail.

The area was mapped on a reconnaissance basis during August and September 1979. Apart from the main roads from Asunción and Concepción to Pedro Juan Caballero and Bella Vista and a few scattered subsidiary roads to Estancias and farms in the area, access is poor. Helicopter support was required to map the area.

In the western part of the area, the topography and vegetation is characterized by a low-lying gently undulating to rolling landscape, covered, for the most part, by open natural grassland, with small areas of sub-tropical to savannah forest along water courses and on some hill tops.

To the east, this relatively flat landscape gives way to a topography consisting of escarpments, mesas, buttes, and extensive irregular plateaus. These features rise successively in elevation to the east to a maximum of 600-800m above sea level. This landscape is covered mainly by thick sub-tropical rainforest which in places has been extensively cleared by logging and/or farming operations. Open grassland is present locally, and patches of thick bamboo are present along water courses.

A third type of topography, characterized by steep hills and ridges, is present within, and in the area immediately surrounding the alkaline intrusive complexes.

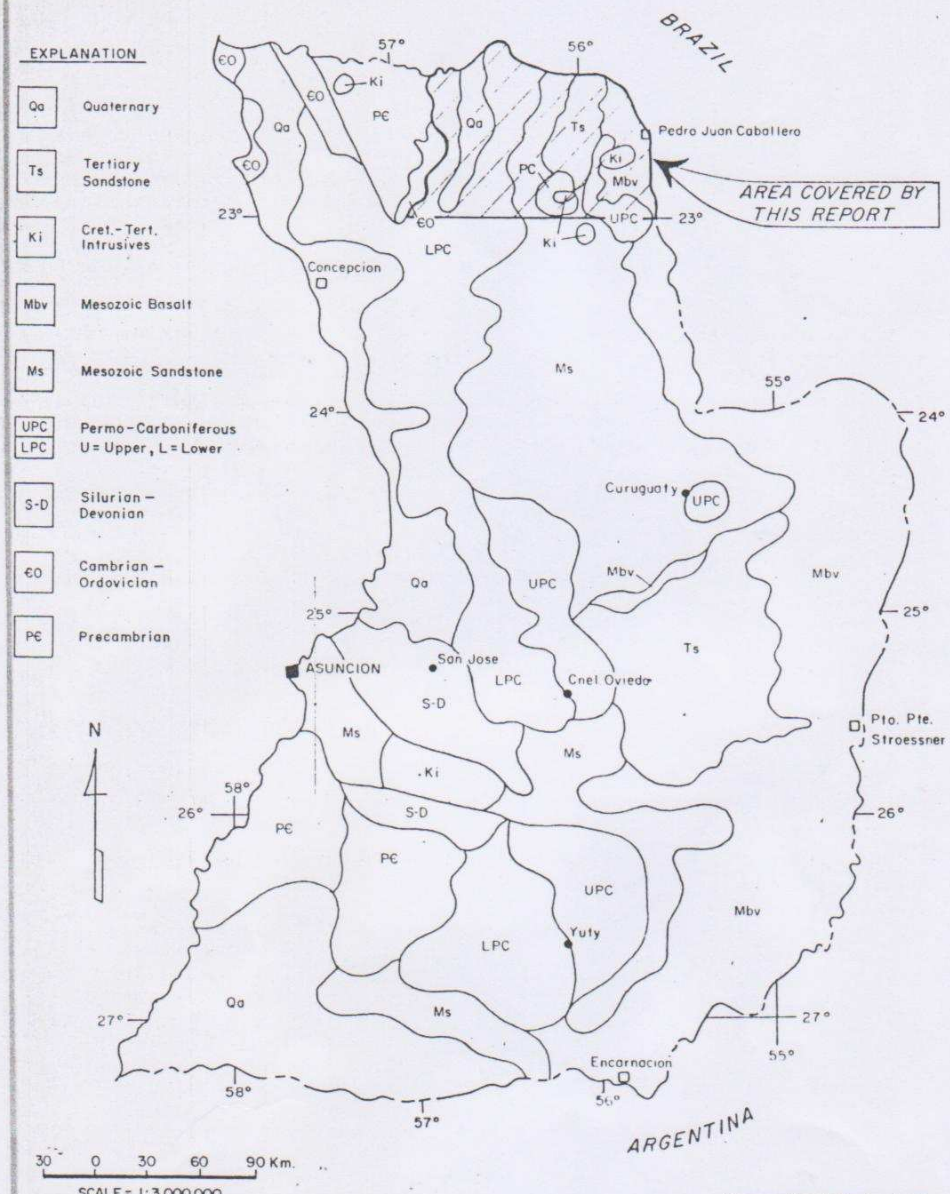
Previous reconnaissance investigations have been carried out in the area by several Anschutz geologists, and A. Patiño (1979) mapped in detail the sediments around the Chirigüelo complex. The various reports describing this work are listed in the references.

GENERAL GEOLOGY (Reference Plate 1)

Broadly, the geology of the area can be described in terms of three groups of rocks.

Alkaline complexes and marginal host rocks

In the central part of the study area two alkaline complexes of Cretaceous age are exposed. These have been described in detail in other TAC reports and will not be discussed here.



Generalized Geologic Map
—Eastern Paraguay—

FIGURE 1
LOCATION

Adjacent to, and rimming these complexes are up-domed zones of pre-Gondwana sedimentary and metamorphic rocks. The sediments are mainly clean quartz sandstones which are correlated with the Silurian sandstones (Caacupé Formation) to the south. The metamorphics are part of the Precambrian basement underlying the Paraná basin.

Gondwana sequence of the Paraná basin

The bulk of the area is occupied by Upper Palaeozoic and Mesozoic sedimentary and volcanic units of the western Paraná basin sequence. These comprise extensive deposits of Lower Permo-Carboniferous glacial rocks, relatively thin massive sandstone and alternating sandstone-siltstone units of Upper Permo-Carboniferous age, and massive sandstone deposits of Mesozoic age. The uppermost unit is comprised of continental flood basalts.

Surficial deposits

Minor deposits of Quaternary alluvium are locally present along the larger rivers, and extensive thin deposits of laterite are developed on the LPC glacial rocks.

Apart from up-doming and local faulting associated with intrusion of the alkaline complexes, the area is structurally little disturbed.

GONDWANA STRATIGRAPHY

Within the Gondwana sequence of the study area, seven mappable stratigraphic units have been recognized. These are described from oldest to youngest, as follows.

LOWER PERMO-CARBONIFEROUS (LPC) GLACIAL ROCKS:

The bulk of the western part of the area is occupied by an extensive and rather monotonous sequence of glacially-derived sedimentary rocks. Within this sequence, three main facies have been mapped; (a) massive diamictite, (b) bedded diamictite, (c) sandstone lenses in diamictite.

Massive diamictite

The bulk of the glacial sediments are composed of massive uniform structureless deposits of unsorted or very poorly sorted material ranging, for the most, part from silt to coarse sand in grain size. In many places, rounded pebble to cobble sized clasts are dispersed throughout this unsorted sand-silt matrix.

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These rocks are almost invariably dark red or red-brown in color, and are typically strongly indurated. Grey mottling is locally present where irregular patches of secondary reduction have been superimposed on the primary red color. Thin calcite veins, and thin red shale bands and lenses are also present locally.

Where pebble and cobble clasts are present, there is always a high matrix to clast ratio, and the clasts are invariably composed of granite, quartzite, and sandstone (of Precambrian provenance).

Similar rocks to those described above are widespread in Late Palaeozoic sediments throughout southern South America and have been termed diamictites (Frakes and Crowell, 1969). These authors briefly define diamictites as "poorly sorted rocks containing a mixture of particles from clay to boulder size" (1969 p.1009), and interpret them to have formed by rapid reworking and redeposition by subaqueous mud flows and debris slides, where large amounts of debris are rapidly dumped by glaciers and glacial outwash streams as they enter the sea.

Bedded diamictite

Within the massive diamictites are numerous occurrences of poorly to well bedded generally sub-horizontal sequences of highly indurated dark red to red-brown shale and siltstone, with subordinate intercalations and lenses of red, brown or purple sandstone or pebbly sandstone. These sequences are usually thin to medium bedded (individual beds range from less than 10 cm to about 50 cm but the 10-20 cm range predominates), but, locally, beds are up to 3m thick.

Individual beds of sandstone or siltstone within the well bedded sequence display the same unsorted texture as the massive diamictite. Therefore, the term diamictite is also applied to the bedded rocks.

Because of the poor exposure within the glacial sequence it is not possible to determine how extensive are individual outcrops of bedded rocks within the massive diamictite. However, the hatched zones in unit LPC on the map show the approximate extent of localitites where bedded rocks have been mapped to date. This suggests that the bedded rocks form lens shaped zones within the massive diamictite.

Sandstone lenses and beds within diamictite

A typical feature of the diamictites in the study area is the widespread occurrence of light-colored feldspathic sandstone, as small lenses and discontinuous lenticular beds within both the massive and bedded diamictite.

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The sandstones range from fine grained well sorted varieties through to coarse grained poorly sorted (and sometimes pebbly) types. Being usually poorly indurated and poorly cemented they are typically very soft and friable. Clasts of indurated red siltstone and shale are common in coarser sand beds. Colors range from light grey through yellow to light brown, and solution banding is common.

Bedding in these rocks is generally thin to medium (individual) beds range from 6-20 cm thick), but locally they are thickly bedded or massive. Bedding orientations are commonly very irregular. Sedimentary structures include small-scale planar and subordinate trough cross-bedding, penecontemporaneous slumps, and scour structures. Thin conglomeratic bands are locally present near the base of some beds, and at a few localities, large (up to 30 cm diameter) indurated (?Silurian) sandstone boulders occur embedded in friable sandstone.

A characteristic feature of these sandstones is the development of a red spotted texture on weathered surfaces. This texture is caused by ubiquitous small discrete hematitic clots, some of which may pseudomorph pyrite.

UPPER PERMO-CARBONIFEROUS (UPC) UNITS:

Two UPC units have been recognized in the area. In the north, a relatively thin sequence of massive sandstone (UPCs) is present between the overlying Mesozoic sandstone units and the underlying glacial diamictites. In the south, exposures of an interbedded sandstone-siltstone-mudstone sequence (UPC), underlying the Mesozoic sandstones, are very similar to the alternating UPC sequence exposed further south in the concession area.

Interbedded Unit (UPC)

The UPC sequence in the southern part of the area was examined in one creek section (section F on map). Here the rocks comprise an upper sub-horizontal thin to medium bedded sequence of siltstone and mudstone, with minor sandstone, which passes down into a medium to thick bedded sandstone sequence.

The upper well-bedded facies consists of grey, green, brown, or red-brown siltstone and mudstone; the wide range of colors is due to secondary oxidation of an original grey sequence. The siltstone is typically weakly cleaved and locally calcareous.

The lower sandstone is medium to coarse grained, moderately sorted but generally well rounded, and poorly cemented (the rock is very soft and friable). Porosity and permeability are high, and abundant yellow solution banding is superimposed on the primary grey color of the rock.

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Massive Sandstone Unit (UPCs)

In the north, a relatively thin massive sandstone unit forms the base of a remarkably extensive and uniform series of massive sandstones in the area. The upper part of this series is composed of typical Mesozoic sandstone units.

The basal sandstone is typically massive(locally medium to thick bedded), fine grained, moderately to well sorted, and poorly indurated. A characteristic feature is the presence of thin to thick horizons of indurated pebbly diamictite, and the common presence of small-scale planar cross bedding. The color of the rock ranges from grey through yellow and grey-brown, and solution banding is present locally.

At four localities, incomplete short sections were mapped in this unit and these are shown in Figures 2 and 3. Although these sections were not measured (thickness was visually estimated), they show the character and relative thickness of beds within this unit.

MESOZOIC SANDSTONE UNITS (Ms, Msi, Msc):

Unit Ms

Overlying the Permian units is an extensive sequence of generally poorly consolidated massive sandstone (Ms). This unit, which correlates with the Misiones Formation, is the most extensive stratigraphic unit in the area.

Along most of its western margin unit Ms is characterized by a distinctive escarpment which ranges from 10m to a maximum of about 50m in height. However, in the north the unit becomes thinner and the escarpment disappears.

This sandstone is typically very thickly bedded or massive, poorly indurated and poorly cemented, and is characterized both by large scale steep cross-bedding and by a distinct lamination. The lamination is caused by thinly alternating bands (0.5 - 1 cm thick) of differing grainsize. At one locality in the south, rare thin beds of brown siltstone were observed.

The color of the rock ranges from light to medium grey or grey brown in the north, to medium or dark brown to reddish brown in the south. A spotted texture due to scattered white felspar crystals in an otherwise red-brown rock is also locally present in the south. Limonite and/or hematite staining is common, and solution-banding is present locally.

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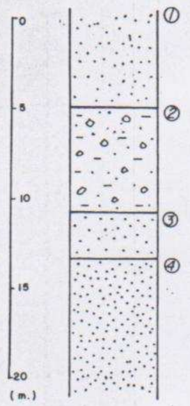
SECTION A



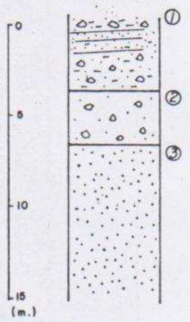
① Massive sandstone, med. grey brown to red-brown, very fine grained, well sorted, sub-rounded, feldspathic (5 %), mod. indurated, small scale planar x-bedding

② Massive pebbly diamictite, dark brown-red with local grey mottling, high indurated

③ Massive sandstone, very dark brown, med. to coarse grained, mod. to well sorted, sub-angular, local grain-size lamination, feldspathic (up to 10 %), poorly to mod. indurated.

④ Massive sandstone, medium red-brown to dark red, very fine grained, well sorted, feldspathic, mod. indurated.

SECTION B



① Thinly bedded to massive pebbly diamictite, dark red to red-brown, interbeds of yellow and grey sandstone with solution banding.

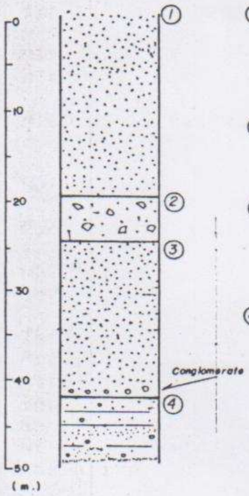
② Massive pebbly diamictite, dark brown-red, local grey mottling highly indurated.

③ Massive sandstone, light yellow to light grey, fine grained, well sorted, sub-rounded, friable, quartzose, one large rounded clast of red pebbly diamictite.

FIGURE 2

Mapped sections in unit UPCs. See Plate I for locations of sections.
(NB: These sections have not been measured; thicknesses were visually estimated.)

SECTION C



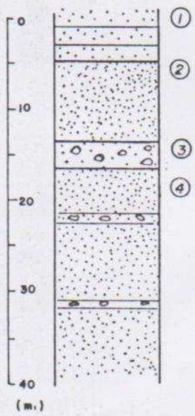
(1) Massive sandstone, medium grey - brown with yellow limonite spots, very fine grained well sorted, sub - angular, poorly to moderately consolidated, slightly feldspathic, small scale planar x- bedding.

(2) Massive, pebby diamictite, dark red, highly indurated.

(3) Massive sandstone, light grey, fine to medium grained becoming coarse towards base, moderately sorted, sub - angular, poorly cemented, slightly feldspathic, permeable.

(4) Thickly bedded to massive sandstone, dark orange brown, very coarse grained, pebby, very friable, poorly sorted, local thin horizons of fine grained red - brown sandstone (cf. top. unit).

SECTION D



(1) Medium to thick bedded sandstone, med. red - brown, med. to fine grained, mod. sorted, sub - rounded, mod. indurated, slightly feldspathic, planar x - bedding.

(2) Massive sandstone, grey to purple - grey (locally red - brown) fine grained, well sorted, strongly indurated.

(3) Massive pebbly diamictite, med. red - brown, highly indurated.

(4) Massive sandstone, med. brown to pink - brown and red brown, very fine grained (locally silty), well sorted, abundant small - scale planar x - bedding, thin interbeds of pebbly diamictite.

FIGURE 3

Mapped sections in unit UPCs. See Plate I for locations of sections.
(NB: These sections have not been measured; thicknesses were visually estimated)

Induration and cementing is generally poor (the rocks are typically very soft and friable), but strong cementing, usually associated with silicification, is present to a minor degree. The most common cementing material is red hematitic clay.

Mineralogically, the sandstones are quartz-rich but minor to moderate amounts (1-12 percent) of felspar are ubiquitous.

Unit Msi

Conformably overlying the lower Mesozoic sandstone unit is a very similar sequence of massive steeply crossbedded sandstone which forms a characteristically spectacular mesa and butte landscape.

These sandstones are generally medium brown to red brown in color but grey or grey brown colors are present locally. Large-scale steep crossbedding is characteristic, but in one locality small-scale low-angle planar cross-bedding is present near the base of the unit. The rocks are also commonly strongly laminated due to thinly alternating bands of differing grainsize and sorting.

Texturally, the sandstones are less variable than the underlying unit, being typically medium to coarse grained, well sorted, and sub-rounded to rounded (locally very well rounded). The unit is usually moderately to strongly cemented, by hematite, and silica. Small siliceous veinlets and silica cement are relatively widespread and may partly explain the more resistant nature of this unit compared to other sandstones in the area.

Unit Msc

In the vicinity of the Chirigüelo and Sarambí alkalic complexes, horizons of very coarse conglomerate (or fanglomerate) are present at or near the top of Unit Msi. These conglomerates contain pebbles, cobbles and some boulders of alkalic material derived from the nearby complexes, and indicate that emplacement of the alkaline complexes occurred during Msi times. These conglomerates also occur in a similar stratigraphic position to the south, in the vicinity of Cerro Guazú.

The conglomerate bearing part of Unit Msi has been mapped as a separate member (Msc).

Units Msi and Msu both contain interbedded basalt flows in their upper parts, where they are in close proximity to, or overlain by the upper basalt unit (Mbv).

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MESOZOIC BASALT (Mbv):

The youngest unit in the Gondwana series is a thick sequence of continental basaltic rocks which overlies units Msu and Msi with conformable and gradational contact. This unit has not been investigated in detail.

SURFICIAL DEPOSITS

Laterite (TQl)

Over much of the area underlain by glacial rocks, small areas of thin flat irregular dissected cappings on topographic highs are clearly visible on aerial photographs. Most of these areas are forest-covered but some are grass-covered.

Most of these features were not examined in the field but at three localities in the northwest areas of thin (1-5m) laterite were found to coincide with these topographic features. On this basis, all similar features recognized on air photos are shown as laterite. Some, if not most of these features probably are due to remnants of a previously more extensive laterite surface, but some may be thin remnants of either LPC or UPC sandstone, as is probably the case north of Toledo Cué. Detailed mapping would be required to resolve this problem.

Alluvium (Qa)

Small areas of Quaternary river deposits are locally present along the larger stream courses. For the most part, these deposits consists of unconsolidated siltstone with minor mudstone and conglomerate.

STRUCTURE

Apart from local strong structural disturbances related to intrusion of the alkalic complexes, the area is little disturbed structurally.

In general, bedding within all the Gondwana sedimentary units is sub-horizontal or gently dipping to the east, and no major faults have been mapped.

The bedded diamictites are almost invariably horizontal or sub-horixontal, although locally dips of up to 10° are present. The sandstone beds within the diamictites are commonly moderately to steeply dipping (20-60°), but even on a local scale the orientations of bedding within this unit are very irregular, and it is apparent that considerable slumping and soft-sediment deformation has taken place within this facies.

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Because of the massive nature of the sandstone units overlying the diamictites, bedding is not easily observed within them. However, where present it is invariably sub-horizontal or very gently dipping (up to 10°), generally to the east or southeast. Large-scale cross bedding is common, and the cross beds commonly dip at angles of up to 30°, with very irregular orientations.

On the southwest flank of the Chirigüelo alkaline complex, the sedimentary sequence is up-domed to a near vertical position adjacent to the complex rim, becoming progressively flatter to the west. Similar up-doming occurs around the Sarambí complex.

Fracturing and minor faulting of the sediments are more pronounced in the areas surrounding the alkaline complexes but no large faults have been mapped to date.

For want of more data, a faulted contact is shown between the alternating UPC sequence in the south and the overlying Ms units.

THICKNESS AND STRATIGRAPHIC RELATIONS OF GONDWANA UNITS

Figure 4 is a schematic representation of the stratigraphic relationships of the various units in the area, as interpreted by the writer.

LPC Glacial Rocks

The indurated red-brown diamictites and intercalated sandstones lenses of unit LPC are very similar to glacially-derived rocks described from the Matto Grosso, to the north in Brazil (Frakes & Crowell, 1969), and the Paraguayan rocks are also undoubtedly of glacial origin.

Because of the poor exposure it is not possible to determine the thickness of the glacial deposits in the western part of the area. However, on the southwest flank of the Chirigüelo alkaline complex, an excellent section of LPC rocks (from Silurian sandstone at the base to Ms sandstone at the top) is exposed in the up-domed host rocks. This section is shown in Figure 5.

From this section it can be seen that the LPC sequence is at least 575m (1900 ft) thick, and, if that part of the section interpreted to be Itacurubí equivalents also belong to the LPC sequence, the total thickness probably exceeds 1000m. The thickness probably decreases westward towards the Apa High.

UPC Units

The alternating sandstone-siltstone-mudstone sequence mapped as UPC in the southern part of the area is very similar to UPC rocks exposed further south in the concession area, and is overlain by Mesozoic sandstone. Therefore, there is little doubt that these rocks are of UPC age. Their thickness is not known.

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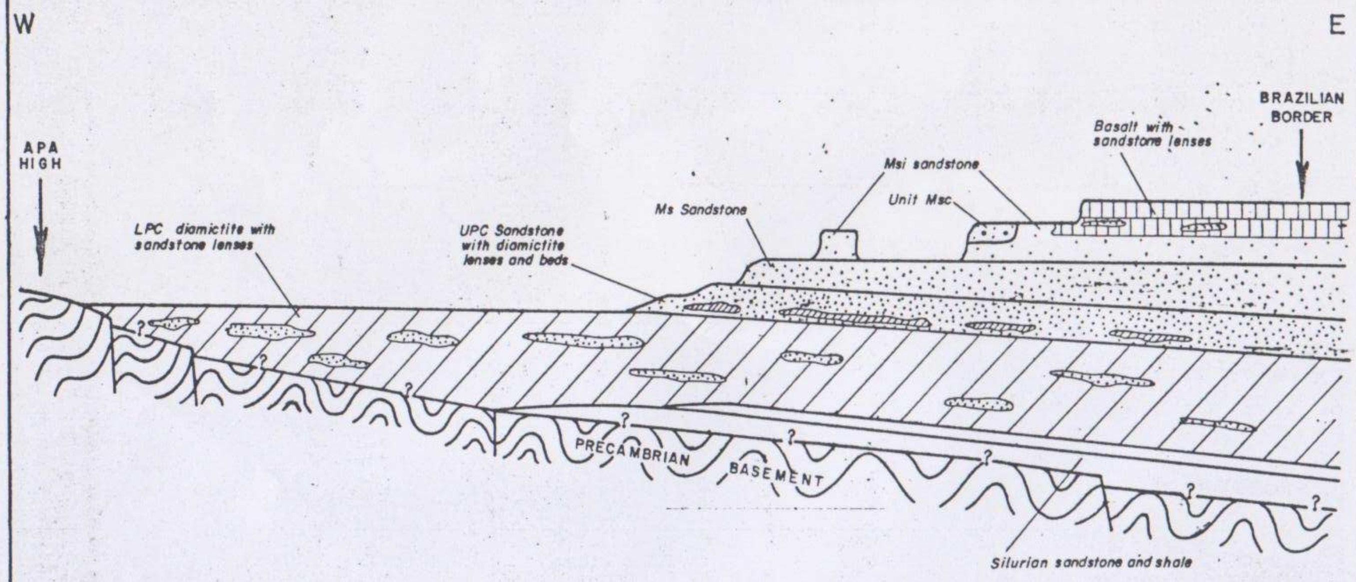

FIGURE 4

Schematic E-W section showing relations of Gondwana units to each other, and presumed sub-surface relations of Silurian Sandstone and Precambrian basement.
(Alkaline complexes and related structural disturbances are not shown.)

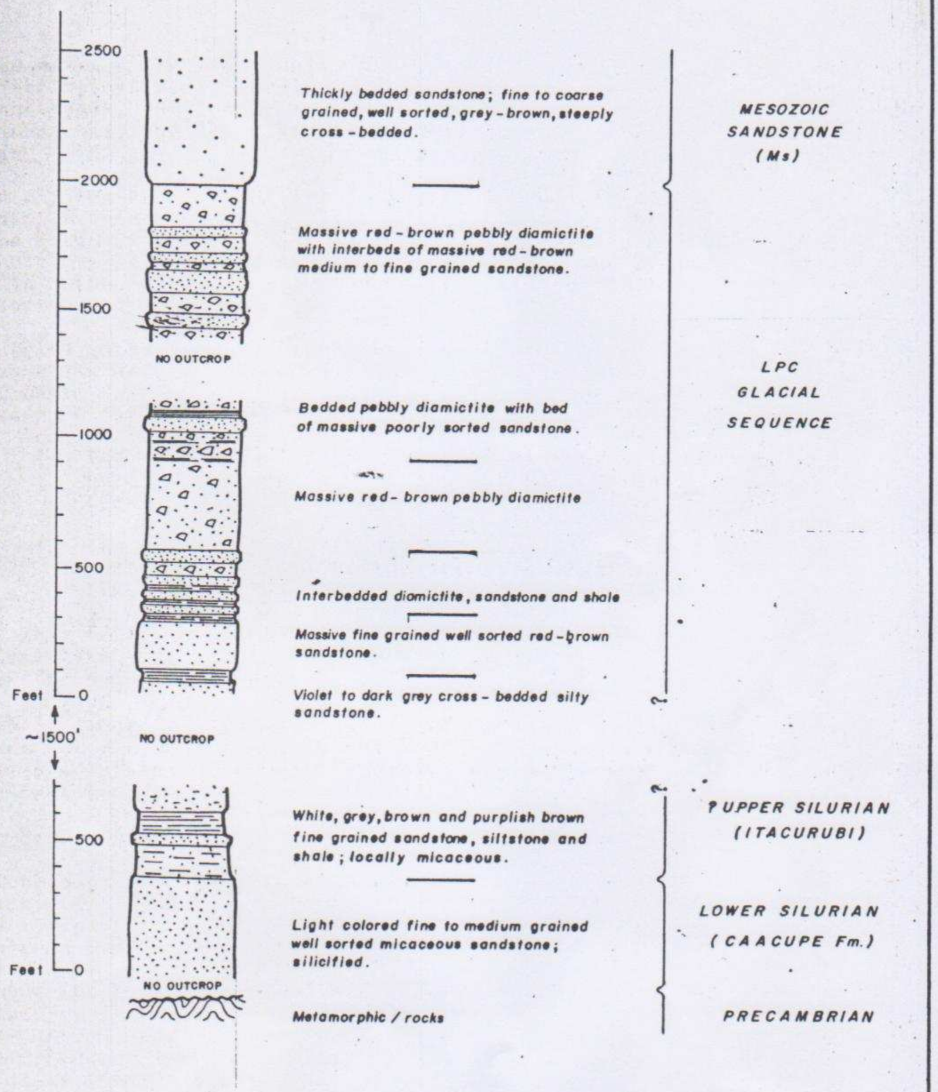

FIGURE 5

SIMPLIFIED SECTION OF THE GONDWANA-LOWER PALAEOZOIC SEQUENCE ON THE SW FLANK OF THE CHIRIGUELO COMPLEX

(Measured by D.S.Hutchison and F, Wiens)

The massive sandstone unit (UPCs) in the north is more problematical. Lithologically, this unit is very similar to the overlying Mesozoic sandstones, but the presence of interbedded diamictite clearly establishes that the basal sandstone unit in the north is not of Mesozoic age.

An alternative possibility is that this unit is of LPC age. Thick massive sandstone units within diamictites have been reported from the Mato Grosso (Frakes and Crowell, 1969), and unit UPCs is lithologically somewhat similar to the lenses and beds of sandstone within the diamictites to the west. This possibility cannot be disproved.

A third interpretation (and the one adopted here) is that the basal sandstone unit is of UPC age, and that deposition of UPC rocks north of Cerro Sarambí was restricted to a sandstone facies. Supporting evidence for this interpretation includes:

1. The presence of a several tens of metres thick sandstone unit at the top of unit UPC north of Coronel Oviedo (Chen, 1978).

2. The presence of a thick sandstone-siltstone unit (Rio Do Rastro Formation) at the top of the Permian in Brazil (Landim and Fulfaro, 1972).

If this interpretation is correct, the presence of intercalated diamictite beds within the sandstone indicate a conformable and gradational contact between units LPC and UPC.

The sections in Figures 2 and 3 indicate that unit UPCs probably does not exceed 50-60 m in thickness where it is exposed along its western margin. The unit probably thickens down-dip to the east beneath the Mesozoic cover.

<u>Ms Sandstone</u>

Along most of its western margin this unit forms a distinctive escarpment from 10-50m high, the base of which is taken as the base of the unit. The unit thins rapidly to the north, appears to thicken gradually to the south, and probably thickens to the east.

Where the base of the unit is not defined by the escarpment, features such as large-scale steep cross-bedding, grain-size lamination, and the lack of small-scale planar cross bedding and interbedded diamictite, help to distinguish it from the lithologically similar underlying unit.

The nature of the contact between units UPCs and Ms is not known.

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Msi and Msc Sandstones

Although these rocks are, in lithology and color, very similar to the underlying Ms sandstone, they can be easily distinguished from the latter by their distinctive mesa and butte ladforms which are topographically above (i.e., resting on) the undulating Ms plateau.

Intercalations of basalt flows are present in the upper part of both these units, while beds and irregular lenses of sandstone are also present within the overlying basalt sequence (Mbv). These features indicate that a conformable and gradational contact is present between units Msi/Msc and Mbv. The contact between unit Ms and the overlying Msi/Msc units appears to be conformable.

The thickness of this unit, as represented in the remnant mesas and buttes, does not exceed 40-50 m, but, in common with the other Gondwana units of the area, it probably thickens to the east.

DEPOSITIONAL ENVIRONMENTS

Because the mapping which forms the basis of this report was reconnaissance in nature, insufficient data was gathered to make confident reconstructions of depositional environments. However, some preliminary conclusions can be drawn.

Glacial Rocks

The rocks described as diamictites in this report can be correlated with extensive similar deposits throughout southern South America.

Frakes and Crowell (1969 p.1009) state that these rocks, including those of the Paraná Basin, are of marine origin because of .....' the abundance of marine faunas interbedded with them'. The sandstone lenses interbedded within the diamictites have some features suggestive of a fluvial origin. These include small-scale planar and trough cross-bedding, scour marks, poor sorting, and, in places, small lens-shaped sand bodies within diamictite are clearly visible in outcrop. However, these features are not definitive for a fluvial environment, and in a high energy shallow-marine environment where abundant glacial debris is being dumped by outwash streams and sub-aqueous mudflows, it is possible that sandstone bodies with similar features could be deposited. Thus, it is likely that the glacial rocks were deposited in a sub-aqueous, probably marine environment.

UPC Rocks

The alternating sequence of UPC rocks in the south contains thin intercalations of limestone southeast of Cerro Guazú, and is similar to UPC sequences in the southern part of the concession area which are thought to represent deltaic to shallow-marine (or lacustrine) deposits.

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Therefore, a similar depositional environment is assumed for the alternating facies in the north.

The presence of small-scale cross bedding in the massive sandstone unit in the north indicate that at least part of this unit was deposited by currents.

However, whether these currents were of fluvial or marine/lacustrine origin is not known. The uniformity, the high degree of sorting, and the lack of bedding in this unit suggest deposition in a moderate energy stable environment. However, with the data presently available, it is not possible to reliably reconstruct the depositional environment for this unit.

Mesozoic Sandstone Units

The massive character, the high degree of sorting and rounding, and the large-scale steep cross lamination of the Mesozoic units suggest deposition of these rocks mainly took place by aeolian processes in a desert environment. In places, small-scale cross bedding and conglomerates indicate local fluvial conditions, and in unit Msu fanglomerates are probably present.

URANIUM POTENTIAL

Although sandstones are abundantly present in the area, on first impressions their uranium potential appears to be low.

Glacial Rocks

The small lenses and beds of sandstone in the glacial diamictites are, in terms of their lithology, porosity, and permeability, good host rocks, and the enclosing impermeable diamictites form excellent permeability barriers.

However, individual sandstone bodies are too thin and of too limited areal extent to enable sufficient concentration of uranium to make ore. In addition, their enclosure by impermeable diamictite renders them largely inaccessible to mineralizing solutions.

UPC Rocks

Siltstones and sandstones in the alternating UPC sequence to the south carry anomalous radioactivity at a number of localities east and southeast of Cerro Guazú. Chemical analysis of samples from some of these localities indicate uranium and/or uranium & thorium mineralization (see Appendix 1).

While the origin of this mineralization is not yet clear (it may be due to alkalic-related hydrothermal processes), its presence in a

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rock sequence which correlates with highly prospective UPC rocks to the south indicates the high potential of the alternating UPC facies.

The potential of the UPC massive sandstone unit to the north is uncertain. The bulk of this unit is composed of fine grained well sorted friable sandstone, the permeability of which appears to be at least moderately good. Solution banding, present locally, indicates that solutions have moved through at least part of the unit, although whether these features are due merely to recent weathering processes is not known.

Permeability barriers, of the type normally expected in a good sandstone environment (for example, beds and lenses of shale in a fluvial sequence) are not present, but the diamictites below and within the unit provide barriers to solutions percolating downward. Therefore, providing a source of uranium and reductants are present, this unit should have some potential for mineralization.

Mesozoic Sandstone Units

The basal Mesozoic sandstone unit (unit Ms) is a highly permeable and porous rock with abundant solution banding, and, although it is mostly oxidized, grey reduced areas are present locally.

However, these positive factors are offset by the lack of suitable barriers to solution flow within or beneath the unit, and the apparent lack of reductants. Therefore, this unit is considered to have low uranium potential.

For similar reasons, the upper Mesozoic units are also thought to have low potential, although suitable environments related to the alkalic-complex derived conglomerate and fanglomerate lenses may be present.

CONCLUSIONS AND RECOMMENDATIONS

Of the Gondwana sediments described in this report, only two units are considered to have significant potential for sedimentary-type (i.e., roll-front and/or related deposits) uranium mineralization. These are:

(1) The alternating sequence of UPC rocks in the southern part of the area.

(2) The massive basal sandstone unit, of probable UPC age, in the western central part of the area.

The potential for other types of mineralization in these rocks (e.g., related to the alkaline intrusive complexes) has not been investigated.

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It is recommended that follow-up work in the area consist initially of reconnaissance core drilling along existing roads in order to obtain initial sub-surface data on stratigraphy and potential uranium host environments.

The entire area of UPC or younger units west of the basalt cover will be included in the 1980 detailed airborne survey and it is recommended that drilling not commence until this data has been fully interpreted, as it may be possible to define drill targets more precisely.

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TABLE 1 - ANALYTICAL DATA FOR ROCK SAMPLES FROM THE NORTHEASTERN PERMO-CARBONIFEROUS

Sample #	Locality	Lithology	Fe_2O_3	U_3O_8	ThO_2	As	F	Mo	V	Se	Mn	Co	Ni	Cr	Cu	Pb	Zn	Ag
8608	Immediately E of the Apa High; LPC	Feldspathic sandstone with solution banding (70 cps)	3.3	1	<30	1	210	<5	36	<.5	390	7	15	50	11	49	13	<1
8609	"	Poorly sorted pebbly sandstone with hematitic spots. (70 cps)	1.3	<1	<30	<.5	75	<5	11	<.5	65	<5	<5	5	3	30	9	<1
8677	East of Estancia Santa Rosalina; UPC	Grey feldspathic sandstone with solution banding. (95 cps)	3.3	<1	<30	1	350	<5	28	<.5	120	<5	7	27	9	24	23	<1
8680	Northeast of Cerro Guazú; UPC	Grey siltstone (200 cps)	7.2	3	<30	33	800	<5	65	<.5	580	15	37	70	35	32	62	<1
8682	"	Laminated grey siltstone. (210 cps)	3.9	<1	<30	15	340	<5	60	<.5	440	<5	20	45	27	30	52	<1
8685	"	Fine grained gray sandstone with solution banding. (120 cps)	2.1	1	<30	<.5	170	<5	17	<.5	198	<5	<5	10	13	24	16	<1
8688	East of Cerro Guazú; UPC	Grey feldspathic sandstone with carbon trash (250-400 cps)	4.3	154	248	67	>5000	<5	56	<.5	2540	25	23	38	[illegible]	50	86	<1
8692	East of Estancia Santa Rosalina; UPC	Red-brown sandy siltstone with organics. (300 cps)	4.7	12	124	34	3850	<5	92	<.5	5000	26	23	80	29	100	57	<1
8693	"	Thin band carbonaceous matter in red-brown siltstone. (400-450 cps)	5.0	18	<30	42	3900	25	340	<.5	>5000	166	78	110	84	1080	56	<1

* Results in percent. All other values in ppm. Analysed by Geosol using semi-quantitative optical emission spectrography.

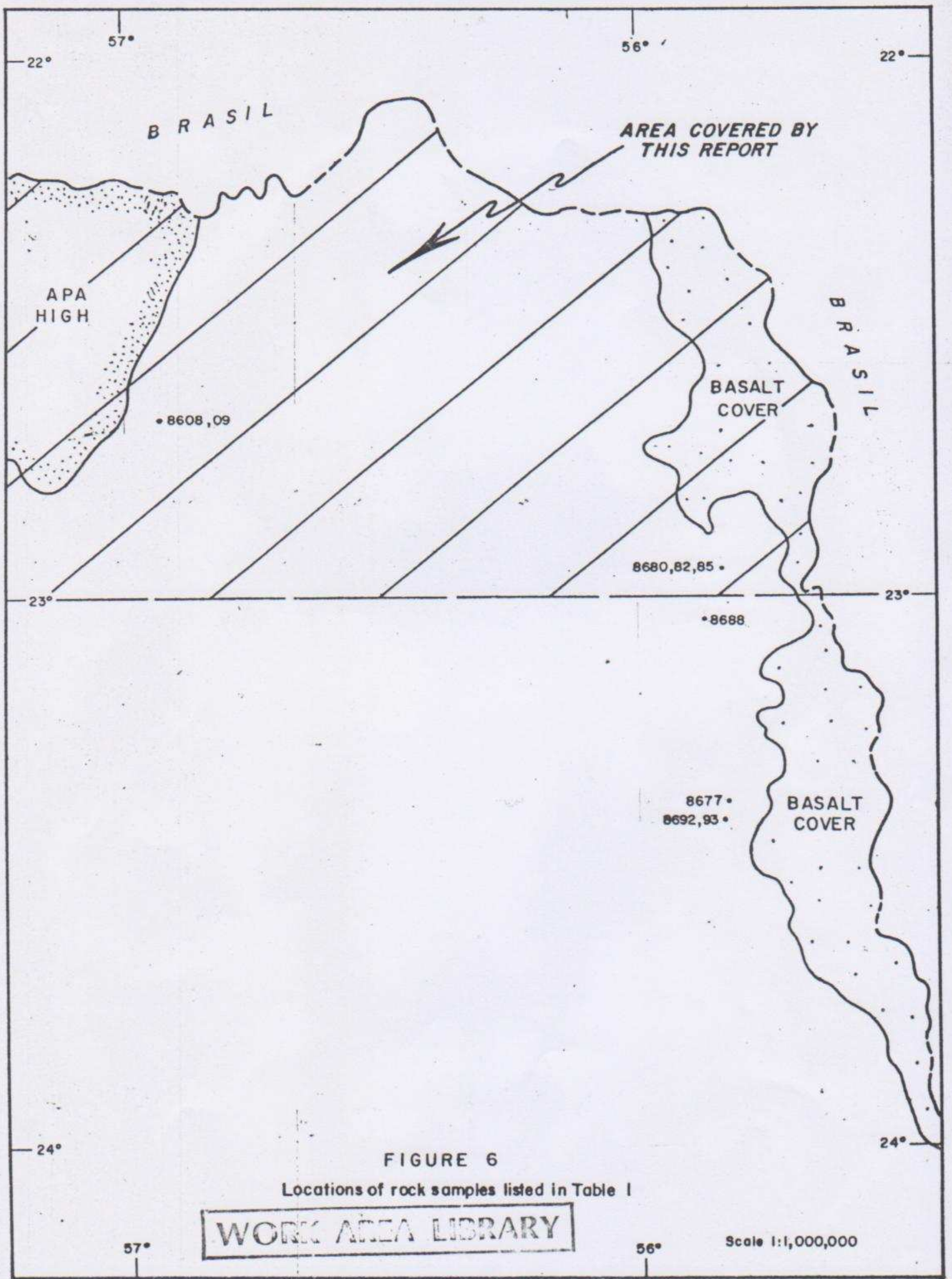

FIGURE 6

Locations of rock samples listed in Table I

APPENDIX 1

SIGNIFICANCE OF ROCK GEOCHEMICAL DATA FOR PERMOCARBONIFEROUS ROCKS IN THE NORTHEAST

Table 1 lists the analytical results of a number of rock samples collected from the Permo Carboniferous sequence in the northeastern part of the concession area. These locations are shown in Figure 6. The samples were collected on a selective basis, using criteria such as the presence of anomalous radioactivity and/or solution banding.

LPC sandstones

Samples 8608 and 8609 were collected from an area of very low order Bi and Bi/Tl airborne radiometric anomalies associated with sandstone lenses in the LPC sequence adjacent to the eastern flank of the Apa High.

Ground follow-up in this area found no zones of anomalous radioactivity on the ground and the airborne anomalies are thought to be mainly caused by rock/soil contrasts.

The sandstones in the area are friable, feldspathic, and extremely permeable, and solution banding is present locally. However, for reasons outlined in the text of this report, the uranium potential of these rocks is considered low. The analytical data supports this conclusion.

UPC sandstones and siltstones

The remaining samples (8677-8693) were collected from the sequences of alternating UPC rocks exposed east and southeast of Cerro Guazú.

Samples 8677 and 8685 are solution-banded (i.e., oxidized) sandstones with no anomalous radioactivity. The analytical data indicates that these samples are not mineralized.

Samples 8680 and 8682 are weakly radioactive (200 cps) reduced grey siltstones from northeast of Cerro Guazú. The analytical data shows that, of the roll-front suite of elements, As is anomalous in both samples, and Ni and Cr are weakly enhanced in one or both samples. However, uranium is not anomalous.

Sample 8688 is a moderately radioactive (up to 400 cps) reduced sandstone from the UPC rocks east of Cerro Guazú. This sample contains 154 ppm U and is also anomalous in As, Co, Cr, Pb and Zn - all of which are elements commonly associated with sandstone-type uranium mineralization. However, it is strongly anomalous in Th, F, and Mn which are <u>not</u> normally associated with this type of mineralization.

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Numbers 8692 and 8693 are samples of moderately radioactive (300-450 cps) red-brown (oxidized) siltstone, and thin bands of carbonaceous material within the same siltstone, respectively. The analytical data shows that the mineralization in No. 8692 is very similar to No. 8688, being anomalous in U, As, Co, Ni, Cr, Pb and Zn and also strongly anomalous in Th, F, and Mn. The carbonaceous material (No. 8693) is moderately to strongly anomalous in all these elements (with the exception of Th) and is also anomalous in Mo, V, and Cu.

Discussion

The anomalous element suite in the mineralized radioactive rock samples from the UPC rocks east and southeast of Cerro Guazú is, for the most part, compatible with tht element suite commonly associated with low-temperature sandstone-type uranium mineralization. However, most of these samples also contain strongly anomalous Th, F, and Mn which are very rare if not absent in sandstone-type deposits; these latter elements, or at least Th and F, are commonly associated with higher-temperature igneous-related uranium mineralization.

Two interpretations are possible:

(1) The mineralization is due entirely to igneous-related hydrothermal processes.

(2) The mineralization is due to younger igneous-related processes superimposed on an earlier period of low-temperature sandstone-type mineralization.

The only known igneous rocks in the area are the alkalic complexes of the Chirigüelo-Sarambí-Guazú alkaline province, and the continen-flood basalts.

The latter are doubtful sources of uranium-rich hydrothermal fluids, but the analytical data is not definitive in indicating an alkalic source for the fluids. More work, particularly geochemical sampling, is required to resolve this problem of genesis of the mineralization in the northeastern Permocarboniferous rocks.

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