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SEDIMENTOLOGY AND PETROLOGY OF THE SPEEWAH GROUP AND PENTECOSTE SANDSTONE (KIMBERLEY BASIN, WESTERN AUSTRALIA)

RIASSUNTO. — Vengono illustrate da un punto di vista petrografico-sedimentologico le formazioni clastiche proterozoiche dello Speewah Group e la Pentecoste Sandstone del Kimberley Group (Kimberley Basin, Western Australia).

Le formazioni dello Speewah Group si sono depositate in un ambiente continentale fluviale prevalentemente di tipo alluvial plain e con sporadici episodi palustri e di piedmont type.

La parte inferiore del gruppo deriva dallo smantellamento di un substrato vulcanico, mentre verso l'alto prevalgono apporti dal basamento cristallino e da preesistenti formazioni sedimentarie.

La Pentecoste Sandstone si è depositata in un ambiente continentale prevalentemente di tipo alluvial-plain con episodi di piedmont type; nel membro medio si riconoscono episodi di sedimentazione costiera.

La parte inferiore della formazione deriva dallo smantellamento di uno zoccolo cristallino e di rocce sedimentarie preesistenti; nel membro intermedio gli apporti sono prevalentemente granitici, mentre nel membro supriore prevalgono i frammenti di rocce sedimentarie preesistenti.

I caratteri diagenetici più evidenti comuni a tutte le formazioni studiate sono un'intensa silicizzazione delle facies più povere di matrice argillosa, la ricristallizzazione e sericitizzazione della matrice argillosa associata a più o meno intensi fenomeni di ematitizzazione.

La misura di numerose strutture sedimentarie nelle diverse formazioni ha permesso di ricostruire la direzione delle paleocorrenti e la loro variazione durante l'evoluzione del bacino.

ABSTRACT. — Sedimentological and petrographic investigations on the Proterozoic clastic Formations of the Speewah Group and the Pentecoste Sandstone (Kimberley Group) in Kimberley Basin, Western Australia, were carried out.

Speewah Group Formations were deposited in a continental fluviatile environment mainly of alluvial plain type and occasionally of swampy flood-plain and piedmont type.

The lower part of the Speewah Group derives from the erosion of a volcanic basement whilst towards the top it is derived from mostly igneous and metamorphic rocks and from older sediments.

The clastic sediments of the Pentecoste Sandstone were also deposited mainly in a continental environment of alluvial-plain type. The middle portion of the sequence occasionally shows some paralic episodes; the upper part shows some piedmont episodes. The lower part of the Formation derives predominantly from the erosion of an igneous and metamorphic basement and from preexisting sedimentary rocks. In the middle part clasts of granitic composition are predominant, whilst the upper part is made up mostly of clasts from older sediments.

The measurements of several sedimentary structures occurring in the sediments of the Formations taken into consideration enabled the directions of paleocurrents and their variations during the deposition of the above-mentioned Formations to be defined.

A high degree of silicification of the sediments, recrystallization and sericitization of the clayey matrix, together with more or less strong haematitization, are the outstanding and more common diagenetic features of all the Formations under investigation.

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Introduction and location

The Kimberley region represents the northern extension of Western Australia, The region is covered by the Carpentarian sediments of the Kimberley Basin, bounded on the south-western and south-eastern borders by a Mobile Belt made up of sedimentary sequences similar to those of the Basin. These sequences are highly dislocated and show many unconformities. Along the narrow Mobile Belt, under Proterozoic sediments, the folded and metamorphosed Archean sediments of Halls Creek Group occur.

Our investigations deal mainly with the clastic Proterozoic formations of the Speewah Group and the upper part of the Kimberley Group (Pentecoste Sandstone), occurring in the south-eastern portion of the Basin along the border of the Mobile Belt (Table 1).

TABLE 1

Simplified stratigraphy of the East Kimberley Region

Carpentarian		Hart Dolerite
		— Unconformity —
	Kimberley Group	Pentecoste Sandstone Elgee Siltstone Teronis Member Warton Sandstone Carson Volcanics King Leopold Sandstone
		— Local unconformity —
	Speewah Group	Luman Siltstone Lansdowne Arkose Valentine Siltstone Tunganary Formation O'Donnell Formation
		— Unconformity —
Proterozoic	Whitewater Volcanics Lamboo Complex	Unconformity
Archean or Proterozoic	Halls Creek Group	Olimpio Formation

(modified from Dow and GEMUTS, 1969)

The investigated area covers a surface of about 10,000 sq. kms. It lies between longitudes 126°15′ and 127°45′ E and latitudes 17°00′ S and 18°30′ S, and is comprised in the Mount Ramsay, Lansdowne and Dixon Range 1:250,000 Sheets.

Previous geological investigations

The first geological observations and particularly on the presence of gold in the region were made by HARDMAN (1885).

WADE (1924) made a reconnaissance of the East Kimberley region. MAITLAND (1928) briefly described the volcanic rocks occurring in the region and EDWARDS (1943) made a detailed petrological description of the same rocks, for the first time.

MATHESON and GUPPY (1949) mapped the Precambrian rocks near Halls Creek and made reconnaissance in Mount Ramsay and adjoining areas. GUPPY, LINDNER, RATTIGAN and CASEY (1958) presented the first subdivision of the Kimberley Basin sediments.

HARMS (1959) studied the Precambrian rocks of the Kimberley region and made an appraisal of the geology of the entire area.

GELLATLY and DERRICK (1967), DOW and GEMUTS (1967) and ROBERTS, HALLIGAN and PLAYFORD (1968) mapped respectively the Lansdowne, the Dixon Range and

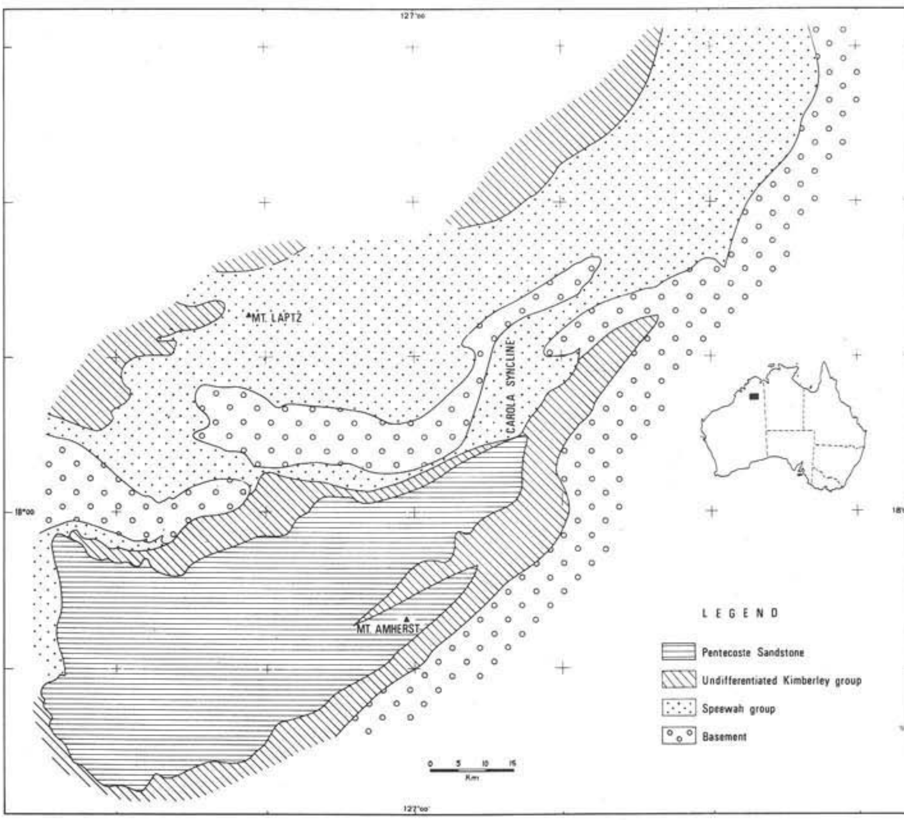

Fig. 1. — Geological sketch of the area studied in the East Kimberley Region (Simplified from Mount Ramsay, Dixon Range and Lansdowne Geological Sheets 1:250,000).

the Mount Ramsay sheets. In the explanatory notes of the mapped sheets the above-mentioned authors present observations on stratigraphic and petrological features of all the formations occurring in the region and on its structure, tectonic history and economic geology.

DOW and GEMUTS (1969) described the results of mapping done by the Bureau of Mineral Resources and the Geological Survey of Western Australia from 1962 to 1964. In their work the basement rocks of the East Kimberley region and the overlying Proterozoic rocks on the East are described.

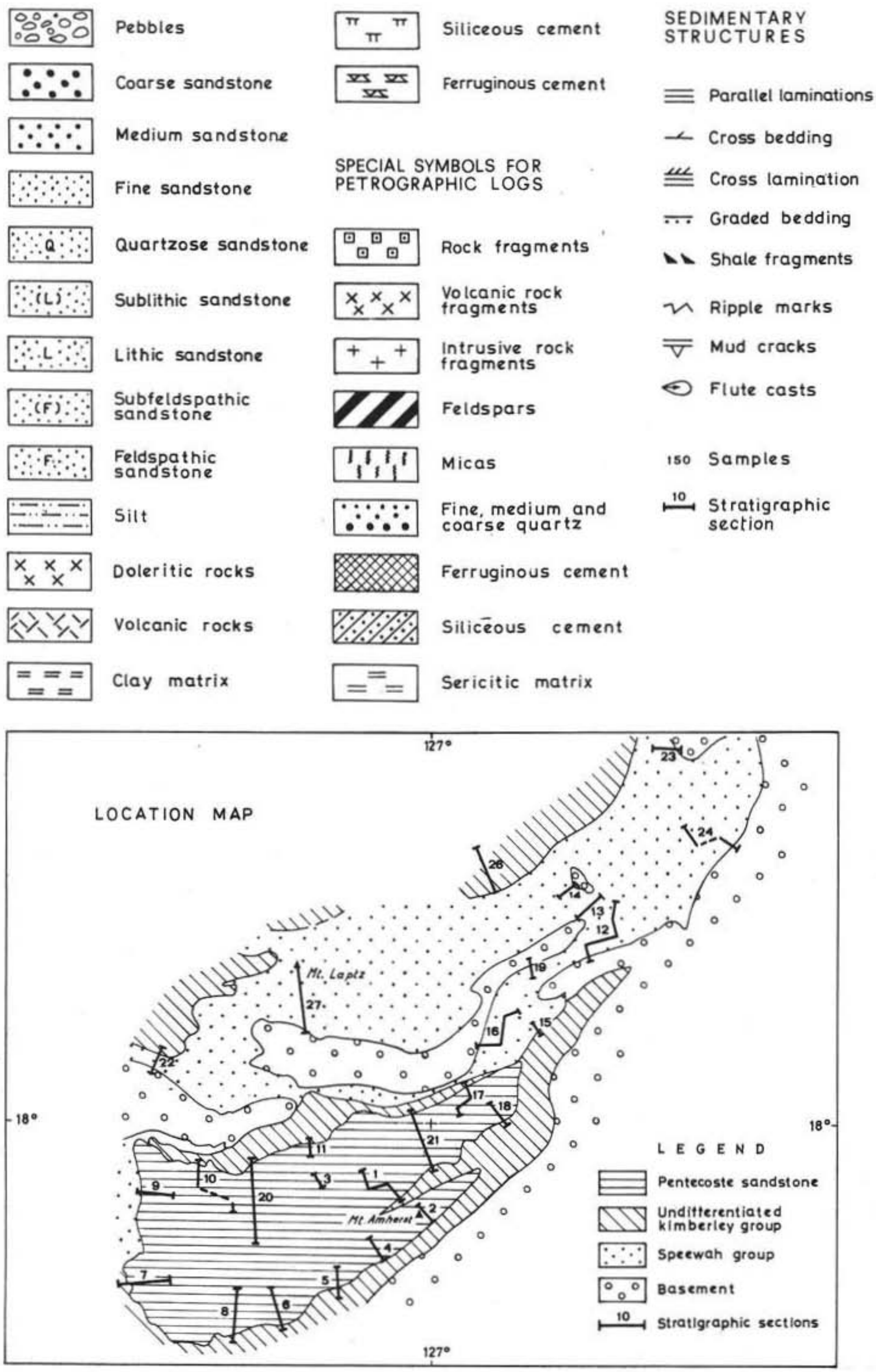

Fig. 2. — Legend to figs. 3, 4, 5, 7 and location map of the sections.

Purpose and Methods of investigation

This study has been made in an effort to understand the geological history of the Speewah Group and Pentecoste Sandstone in the area under consideration.

The research was undertaken to establish the provenance, the transport and the depositional environments of their sequences. The results of such an investigation should indicate the most interesting formations for uranium exploration.

Several detailed stratigraphic sections distributed through the area were measured and described (fig. 2). From each section several samples were collected at regular intervals in uniform sequences and at every change of facies in composite ones so as to get continuous and representative logs.

For the paleogeographic reconstruction of the basin in which the formation were deposited the prevailing directions of paleocurrents in each formation or in a single portion of a formation have been taken into consideration. Such directions are the results of several hundred measurements of sedimentary structures observed in the field.

Petrographic and mineralogical analyses were carried out on 400 samples, following the methods suggested by PETTIJOHN (1949, 1972). Clastic sediments have been classified according to Van Andel classification (1958) in which the terms « graywacke » and « arkose » have been replaced by « lithic sandstone » and « feldspathic sandstone » respectively.

The igneous, sedimentary and metamorphic rocks occurring in the area but not included in the considered formations have been investigated in less detail; still they have been considered within the context of the paleogeographic reconstruction.

Regional Geology

The Proterozoic clastic Formations of the Speewah Group lie unconformably on a basement reported to range from Archean to Proterozoic age (table 1). It consists of folded and slightly metamorphosed geosynclinal sediments (Halls Creek Group) affected by basic and ultrabasic intrusions during early Proterozoic time. The sediments have been affected in the Halls Creek Mobile Zone by a second tectonic stage, Proterozoic in age, that partially changed the sediments into high-grade metamorphics (Tickalara Metamorphics) and was followed by late granitic intrusions. The igneous and metamorphic formations related to this tectonic cycle are gathered in the Lamboo Complex. During the emplacement of late granitic intrusions the basement was partially covered by acid volcanics (Whitewater Volcanics).

After this cycle of igneous activity in the region there began the sedimentation of thick Proterozoic formations in shallow water and/or continental environments. In the area studied these formations, mainly continental, are grouped in the Speewah and Kimberley Groups.

The deposition of the above-mentioned formations was affected by mild tectonics marked by unconformities between the Groups or the formations of the same Group. The tectonic movements were generally accompanied by intrusions of mainly basic rocks (Hart Dolerite). The sediments resulted unchanged and unmetamorphosed but those occurring in the Mobile Zone, the tectonic evolution of which continued to influence the adjacent basins.

Geological sketch and stratigraphy of the studied area

A geological scheme of the studied area is reported in fig. 1. It has been sketched on the basis of Mount Ramsay, Lansdowne and Dixon Range 1:250,000 geological sheets.

The stratigraphy of the Speewah and Kimberley Groups, their mutual relationships and their relationships to the basement are reported in table 1.

Speewah Group

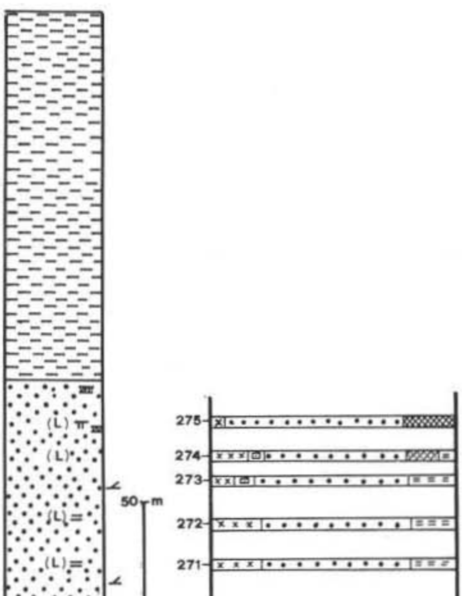

Fig. 3. — Section No. 12 and respective log of the O'Donnell Formation. (Legend in fig. 2).

The O'Donnell Formation overlying unconformably the Whitewater Volcanics and locally the sediments of the Olympio Formation (Halls Creek Group) consists of two members commonly present and easily recognizable in the field. The lower member (figs. 2, 3, 6), 20 to 70 m thick, is made up mainly of pale red and pink coarse to very coarse-grained lithic and sublithic sandstones grading occasionally to microconglomeratic facies. Medium to fine-grained yellow lithic sandstones occur in lens-shaped bodies in the north-eastern part of the area. In the Carola Syncline they represent a rather continuous horizon. Sporadic bands of conglomerates locally occur. They contain pebbles few centimetres in size of quartz and volcanics in a coarse-grained arenaceous matrix. Rare tuffaceous horizons and volcano-clastic sediments occur at the bottom of the Formation.

The sandstones often show cross-bedding structures, mostly of planar type, 10-20 cm thick. The sediments are generally well stratified with 20-50 cm bedding. Other sedimentary structures are: uncommon symmetric ripple marks and frequent clay fragments.

The upper member of the O'Donnell Formation, up to 10 m thick, is mainly represented by yellow or gray-green, thin bedded micaceous siltstones with thin intercalations of medium-fine lithic sandstones and pale green tuffaceous rocks. The more widespread sedimentary structures are represented by ripple marks, mud cracks and subordinate current lineations (flow casts, parting lineations).

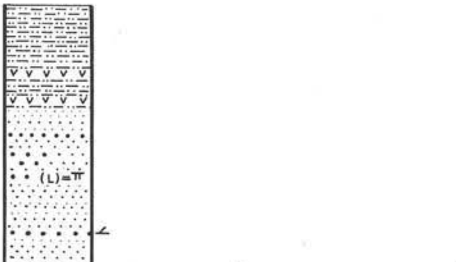

Fig. 4. — Section No. 16 and respective log of the Tunganary Formation. (Legend in fig. 2).

Petrographically the sandstones of the O'Donnel Formation show a variety of features according to the type of transport the clasts underwent and to differential compaction. The framework commonly consists of quartz clasts and lithic fragments that show a good compaction and frequent sign of intergranular penetration.

The grain size ranges from 0.1 to 1.3 mm. The sandstones often show bimodal texture, characterized by 0.5-1.3 and 0.1-0.2 mm fractions. The finer fraction seems to be richer in lithic fragments.

Sorting is generally low to moderate. It is rather good in some sublithic facies showing a trend towards quartz-sandstones. The roundness and sphericity of the grains are very variable, from low to good. In the bimodal facies the coarser fraction seems to be more rounded and spherical. Textural maturity varies from low to moderate. From a mineralogical point of view, the lithic and sublithic sandstones of the O'Donnel Formation represent immature and/or submature sediments and are composed of:

1. - Detrital components: their content varies from 75 to 90 % of the rock.

   a) *Quartz*. It is the most abundant detrital mineral. It represents on the average 65 % of the clasts (min. 55 %, max. 75 %) in lithic facies, 80 % of the clasts (min. 70 %, max. 90 %) in sublithic ones (fig. 6). Depending on the rock source, the quartz can be classified as catametamorphic, epimetamorphic, granitic and volcanic.

   Catametamorphic quartz is always present in small quantities rarely reaching 5 % of the quartz fraction. It is characterized by mono- or polycrystalline grains showing a high ondulatory extinction, a mosaic granoblastic structure, clear uniform boundaries, and it is generally rich in inclusions of micas and other minerals. It derives from highly metamorphosed rocks.

Epimetamorphic quartz, deriving from low metamorphosed rocks, comprises 10 % of the detrital quartz. It is characterized by a mosaic granoblastic medium to fine polycrystalline structure with straight or sutured contours and often shows oriented textures.

Granitic quartz shows generally no well defined shape, equidimensional grains, smooth borders and numerous inclusions (biotite, apatite, zircon). Mirmechitic and subgraphic structures often occur. The crystals show generally normal extinction. Its content reaches 5 % of the quartz fraction.

Volcanic quartz, clearly prevailing (80 %) on the other types, occurs as subangular or rounded clasts characterized by monocrystalline structure, generally straight extinction, satinate surface. Irregular fractures occur within the crystals. It often shows rims and embayments of microcrystalline or criptocrystalline vitric groundmass.

b) *Feldspar*. It is rather minor or absent. Only in rare subfeldspathic sandstones it reaches 10 % of the rock.

It is mainly represented by potash feldspar and albite-oligoclase. The feldspar is generally kaolinized or sericitized.

c) *Micas*. They are irregularly distributed, being more abundant in the silty member. Their mean content, in micaceous sandstones and siltstones, is about 4-5 % of the rock. In some siltstones they reach 10 %. Clastic mica is represented mainly by white mica in fresh large flakes.

Biotite is very subordinate in the arenaceous horizons, whilst in some beds of the silty member, it may predominate. It occurs as large pleochroic flakes, often altered to brown ferrugineous material or to chlorite.

d) *Accessory minerals*. The most common are tourmaline, zircon, apatite and opaques (haematite, leucoxene, magnetite and ilmenite).

Tourmaline, a blue-green type, is sometime abundant (1-2 % of the rock) and represents the most common accessory mineral. It occurs both in rounded clasts, and as individual idiomorphs. Zircon, light red in color, occurs as well-developed prismatic grains, regularly distributed throughout the rock.

e) *Lithic fragments*. They represent, on the average, 35 % of the clasts (min. 25 %, max. 50 %) in lithic sandstones, 20 % (min. 10 %, max. 25 %) in sublithic ones.

They derive from:

e.1) *Volcanic rocks*. They predominate, representing up to 80 % of the lithic fraction. The fragments, variable in size (up to 1.0 mm), commonly subangular, occur as a highly sericitized microcrystalline quartz-feldspar groundmass. In some cases a pylotaxitic and pseudofluidal groundmass showing ignimbritic structures occurs.

The volcanic fragments derive from the erosion of the rhyodacitic Whitewater Volcanics.

e.2) Clayey fragments. They are represented generally by well rounded clasts composed of sericite clay matrix. They often show an inner brown iron-oxide impregnated zone and a lighter outer rim. In many cases the clasts are surrounded by a thin haematite film. Occasionally clayey fragments consist of greenish-yellow biotite and green-brown glauconite. Most of this fragments seem to be derived from recrystallized aphanitic volcanic rocks. They are irregularly distributed and concentrated around Old Bedford Yard, where they comprise 15 % of the rocks.

e.3) *Granitic and metamorphic rocks*. They can reach 10 % of the lithic fraction. In the western portion of the area their content increases.
The fragments are represented mainly by albite-biotite schists white-mica schists, sericite schists, quartzitic and granitic rocks and sporadically serpentine schists.
The fragments derive from the crystalline basement (Lamboo Complex).

2. - Matrix and cement. The sediments of the O'Donnell Formation contain a mean amount of matrix of about 8 % of the rock. Only in some silty facies the matrix can reach 10-15 %. It consists generally of a microcrystalline sericitic mass filling the intergranular spaces. It is often colored in pink-brown tones by evenly distributed very fine-grained iron oxide partilces. In places the matrix is partially recrystallized in bands and nests of white mica flakes, often showing a fibrous-radial structures. Frequently the contours of the clasts show signs of corrosion and replacement by recrystallized matrix.
A siliceous cement is fairly common. It can reach 10 % of the rock. It is represented by quartz rims around clasts, by fillings in pore spaces and often by quartz overgrowths on quartz clasts showing optical continuity.
In some horizon of the arenaceous member a homogeneous haematitic cement, which imparts a pink-purple colour to the rocks, occur.

The O'Donnell Formation can be subdivided in two sedimentary cycles corresponding to the basal arenaceous member and to the upper silty member.

The low textural maturity of the sediments of the basal member, as well as the sedimentary structures they show, seem to indicate an alluvial plain environment, characterized by a relatively high-energy transport. These sediments underwent a partial aeolian reworking, as shown by the high sphericity roundness and bimodal sorting of clasts in some horizon falling within the field of sublithic sandstones grading to quartz-sandstones.

For the silty member, the sedimentary structure seem to indicate a swampy flood plain environment with seasonal emergences, marked by the occurrences of numerous mud-cracks. The low compositional maturity indicates sedimentation close to the source, whilst the mineralogy of the rocks show that they are derived from erosion of a volcanic basement (Whitewater Volcanics) and, to a small extent, of a granitic-metamorphic basement.

Tunganary Formation

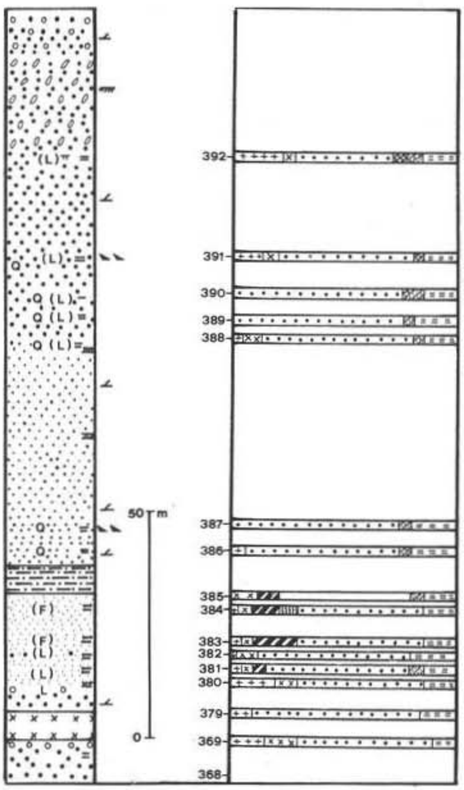

Fig. 5. — Section No. 16 and respective log of the Lansdowne Arkose. (Legend in fig. 2).

The Tunganary Formation, conformably overlying the O'Donnel varies in thickness from 80 to 150 m. The Formation consists mainly of reddish medium to coarse lithic and sublithic sandstones (73 %), with sporadic microconglomerate horizons containing pebbles of quartz and igneous rocks (figs. 2, 4, 6). Subfeldspathic and feldspathic sandstones are common (27 %). Fine and very fine-grained sandstones, at times grading into foliated siltstone beds, occur. The grain size of the sediments often varies vertically and laterally.

Sporadic coarse-grained quartz-sandstones occur in small lens-shaped bodies.

The sediments of the Tunganary Formation show a regular one decimetre thick bedding. The most common sedimentary structures are: cross bedding of the trough type, at times planar, in sets ranging from several cm to some dm in thickness and slightly inclined, symmetrical ripple-marks, mud-cracks and clay fragments.

From a petrographic point of view the Tunganary Formation is made up of mainly sublithic and lithic sandstones grading to the field of subfeldspathic and feldspathic sandstones (fig. 6). These sediments consist of a framework of clasts immersed in a sericitic matrix and/or siliceous cement.

The rocks generally show good compaction, the clasts are frequently squashed together.

The grain size of the clasts ranges from 0.1 to 1.0 mm, but generally lies within the range 0.3-0.4 mm. Occasionally a bimodal distribution occurs. The degree of sorting, roundness and sphericity are rather homogeneous.

Sorting is generally poor, except in some quartz-sandstone horizons which are well sorted.

Roundness and sphericity are commonly low to moderate, except in some quartz-sandstones where the clasts show good roundness and sphericity.

From the point of view of textural maturity the sandstones of Tunganary Formation are mainly immature or submature.

Mineralogically the sediments of the Tunganary Formation are composed of:

1. - Detrital components: their content varies from 70 % to 80 % of the rock.

a) *Quartz*. It is the most abundant detrital mineral, averaging 70 % of the clasts (min. 58 %, max. 78 %) in subfeldspathic facies, 56 % in feldspathic

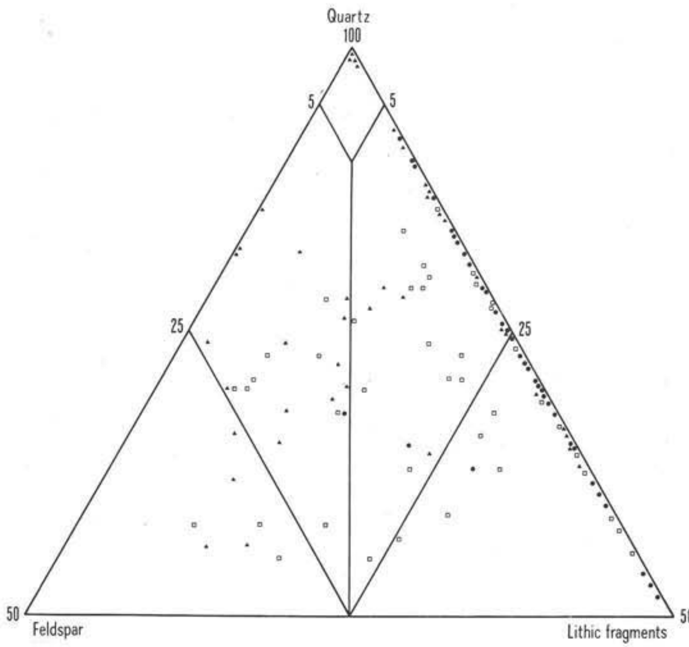

Fig. 6. — Classification of the sandstones of the O'Donnell (●), Tunganary (□) and Lansdowne (▲) Formations.

ones. Its content in sublithic and lithic sandstones varies from 55 to 85 % and from 55 to 74 % of the clasts respectively (fig. 6). It is represented mainly by volcanic quartz (up to 80 %) and subordinately by granitic (up to 20 %) and epimetamorphic (up to 10 %).

b) *Feldspar*. Its content varies from 12 to 35 % of the clasts in subfeldspathic and feldspathic sandstones and from 0 to 20 % in sublithic and lithic ones. These facies are more widespread in the upper part of the Formation.

The feldspar is mainly represented by idiomorphic or rounded 0.5-0.7 mm K-feldspar grains, generally highly kaolinized, with reddish very fine disseminated iron oxides.

Microcline clasts and sericitized albite-oligoclase grains are subordinate.

c) *Mica*. It rarely exceeds 5 % of the rock and it is represented mainly by white mica. Biotite is rather rare and irregularly distributed throughout the rock.

d) *Accessory minerals*. The most common are: tourmaline, zircon, opaque minerals (magnetite, haematite, ilmenite), apatite and rarely rutile. They are evenly distributed.

e) *Lithic fragments*. They can reach 20 % of the clasts in subfeldspathic and feldspathic sandstones and vary from 10 to 45 % in sublithic and lithic ones. They are represented by:

e.1) *Volcanic rocks*. They represent up to 70 % of the lithic fraction and consist mostly of intensely sericitized microcrystalline groundmass, rarely containing phenocrysts of quartz and sericitized feldspar and showing in places fluidal textures, brown-red coloured by disseminated iron oxides.

e.2) *Intrusive and metamorphic rocks*. They are subordinate (30 %) to volcanic material, rarely reaching 50 % of lithic clasts. They are represented by granitic rocks, by quartzites and by albite-micaschists.

e.3) Clayey fragments. They are sporadically distributed throughout the Formation and show the same features as those described in the O'Donnell Formation.

2. - Matrix and cement. The mean content of sericite-clay matrix in the sandstones of the Formation reaches 10 % of the rocks. Contents of 20 % of matrix can be observed in some lithic facies. The siliceous cement too represents on the average 10 % of the rock, being more widespread in medium to coarse grained sandstones. Haematite cement is rather widespread throughout the Formation but in lesser amounts.

The low textural maturity of the sediments of the Tunganary Formation, as well as their sedimentary structures seem to indicate a fluviatile depositional environment of the alluvial plain type. The prevalence of medium to coarse grained sediments, the occurrence of small and irregular fine-grained clayey deposits and the frequent lateral and vertical variation in grain-size seem to indicate a braided-stream regime, in which the transport of clastic material occurs over vast areas through a network of minor channels.

The mineralogical composition of the sediments indicates that they are derived partly from the erosion of a volcanic substratum (Whitewater Volcanics), particularly in the lower part of the Formation, and partly from a granitic and metamorphic basement (Lamboo Complex).

The low textural and mineralogical maturity of the sediments indicates that their deposition took place rather near the source area.

Sporadic bodies of quartz-sandstones, characterized by high compositional and textural maturity, as well as bimodal sorting are related probably to local aeolian reworking.

The *Valentine Siltstone* shows a very variable thickness ranging from few meters to 50-60 m, but it crops out in a continuous and recognizable band between the underlying Tunganary and the overlying Lansdowne Formation, with both of which is conformable.

The Formation is mainly represented by foliated micaceous siltstones, clayey siltstones and shales. These sediments, containing numerous haematitic fragments and fine-grained iron hydroxides, vary in colour from red-purple to gray-green.

In the basal and middle parts of the sequence there are intercalations of fine to medium and coarse-grained subfeldspathic and feldspathic sandstones.

Occasionally these sandstones have a sublithic tuffaceous character and are brown-red to greenish in colour. They generally show good beddings with thickness variable from few centimetres to some decimetres. Sedimentary structures observed in the sediments of the Formation include ripple-marks and current lineations, as well as clay fragments.

Petrographically the siltstones are composed mainly of a micro or crypto-crystalline sericitic and argillaceous groundmass showing local patches of silicification with fine grained mosaic structure quartz and disseminated fine iron hydroxide material.

In this matrix a clastic silty fraction that may reach 20-30 % of the rock occurs. It is mainly composed of quartz, subordinate feldspar and minor biotite and muscovite. Due to grain-size, it was impossible to recognize different types of quartz and to determine the altered feldspar clasts.

The shales consist almost entirely of sericite-clay groundmass described above with disseminated clastic fraction comprising only a small per cent of the rock and composed of quartz, feldspar, muscovite and biotite.

The feldspathic and subfeldspatic sandstones of the Valentine Siltstone are characterized by a clastic framework with minor matrix and cement filling pore spaces.

The clastic fraction, comprising up to 80 % of the rock, is mainly fine to medium and medium-coarse-grained and shows poor to moderate sorting, low to moderate roundness and sphericity. Textural and compositional maturity is very low.

The clastic fraction is composed of quartz (up to 75 %), feldspar and lithic fragments with lesser amount of mica. Quartz is mainly catametamorphic; volcanic one is subordinate, but in tuffaceous facies where it can be predominant. Epimetamorphic quartz is very minor.

Feldspar is always strongly sericitized and haematitized and is represented by K-feldspar, albite-oligoclase and microline. Mica is represented by chloritized biotite and muscovite. Lithic fragments consist for the most part of devitrified crypto and microcrystalline volcanic rocks. Fragments of cherts and haematitic

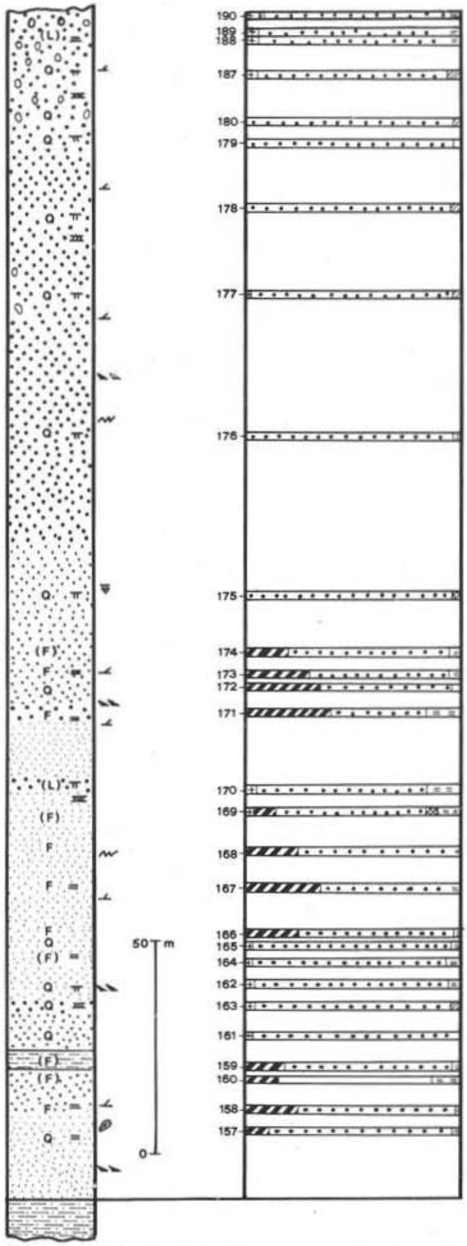

Fig. 7. — Section No. 2 and respective log of the Pentecoste Sandstone. (Legend in fig. 2).

shales also occur. Accessory minerals in very small amounts and generally concentrated in irregularly distributed pockets comprise: zircon, leucoxene, apatite, haematite, oxidized pyrite.

The petrographical, mineralogical and textural features of the Valentine Sandstone, previously described seem indicate that the Formation on the whole was deposited in a swampy flood plain fluviatile environment, with local, more turbolent stages marked by coarser feldspathic facies. The textural and compositional immaturity of the sequence and its mineralogical composition show a provenance from a nearby granitic and metamorphic basement (Lamboo Complex) and, in lesser amount, from volcanic rocks (Whitewater Volcanics).

The *Lansdowne Arkose,* several dozen meters to more than 250 m thick in the northeastern part of the area, overlies the Valentine Siltstone and is in turn overlain by the Luman Silstone with which shows concordant and sharp contacts.

The Formation that can be subdivided into three easily recognizable members, is represented by sublithic (34 %) and lithic (12 %) sandstones associated with subfeldspathic (34 %) and feldspathic (10 %) facies. Quarz-sandstones are subordinate (fig. 6).

The basal member consists of a lower arenaceous complex and an overlying silty one, that reach, on the whole, 20-50 m of thickness. The lower complex is composed of pale red, yellow or red-brown subfeldspathic and sublithic sandstones with clay-sericite matrix. The grain size shows a remarkable variation, both vertically and laterally. Medium coarse-grained facies with one metre thick intercalations of microconglomerates predominate.

Decimetric bedding is common. Planar cross-bedding, ripple-marks, clay-fragments and local graded bedding occur.

The silty complex, 10-12 metres thick, is made up of foliated pink, gray and green siltstones with sporadic intercalations of fine grained massive sandstones.

This silty complex, which represents an easily recognizable marker bed, is almost completely devoid of sedimentary structures.

The middle member of the Formation, reaching a thickness of 130 metres, is mostly represented by subfeldspathic sandstones in the north-eastern part of the area and by sublithic sandstones and quartzsandstones in the West.

The rocks show commonly a light red-brown to pale yellow colour and a very uniform grain size. Medium to medium-fine grained facies predominate in the sequence. Sporadic coarse grained intercalations, particularly in the basal part can be observed.

In the western portion of the area, interbedded volcano-clastic rocks occur.

The bedding is uniform and regular, 30-50 centimetres thick, cross-bedding, mostly planar, sometimes trough type and clay fragments frequently occur.

The upper member, ranging up to 100 metres thick, consists essentially of pink-yellow coarse grained, locally conglomeratic sandstones. These show generally a sublithic character in the lower part of the sequence and grade towards the top into more distinctly lithic facies in the North-West, whilst in the North-East they grade into medium and fine-grained feldspathic sandstones.

In the south-west, conglomerate lenses occur, which contain dark-grey pebbles 4 to 40 centimetres in diameter of lithic sandstones and quartz, showing no preferred orientation. Bedding, a decimetre thick is uniform and regular. The main sedimentary structures are represented by frequent decimetric cross-bedding and clay fragments.

The sandstones of the Lansdowne Arkose are characterized by a framework of clasts, generally well compacted, in places interpenetrated with a fine sericite-clay matrix and/or siliceous and ferrugineous cement in the pore spaces.

The grain size is variable. The lower and upper member are mostly coarse-grained (0.6-0.8 mm) and show local microconglomeratic lenses. The middle member consists mainly of medium and medium-coarse-grained (0.25-0.40 mm) rocks.

Some bimodal horizons composed of both fine and coarse fractions occur.

Sorting is generally poor, rarely moderate. It is good in the bimodal horizons.

Roundness and sphericity vary from very low to moderate.

They are high in quartz-sandstones. In bimodal facies the fine fraction is generally subangular, whilst the coarse one shows higher roundness and sphericity.

The textural maturity of the sandstones of the Formation is therefore low, except for the quartz-sandstones and the bimodal facies that show a mature and supermature character.

The compositional maturity of the sandstones of the Formation is low and very low. Higher values of maturity can be observed only in some bimodal sandstones.

From a mineralogical point of view the sandstones are composed of:

1. - Detrital components. Their content varies from 65 % to 84 % of the rock.

a) *Quartz*. It commonly comprises 98 % of the clasts in quartz-sandstones. In subfeldspathic and feldspathic facies it varies from 65 to 85 % and from 55 to 65 % respectively. In sublithic and lithic sandstones it varies from 65 to 88 % and from 62 to 70 % respectively (fig. 6). It is mainly represented by granitic and catametamorphic quartz (85 %); volcanic quartz occurs in a lesser amount (10 %). Epimetamorphic quartz is very scarse (5 %).

b) *Feldspar*. It represents on the average 20 % of the clasts in subfeldspathic sandstones (min. 10 %, max. 25 %); 30 % in feldspathic ones (min. 26 %, max. 33 %). It varies from 0 to 12 % in sublithic sandstones and it is almost absent in lithic ones and in quartzsandstones. Feldspar is represented mainly by K-feldspar strongly kaolinitized and iron-impregnated, by microcline and albite-oligoclase.

c) *Mica*. It constitutes a small per cent of the rock, on exceptions reaching 15 %. It is mainly represented by phengitic and chloritic types. The last one generally develops on biotite flakes.

d) *Accessory minerals*. The most common are: zircon, monazite, xenotime, tourmaline, haematite, Ti-oxides and apatite. Occasionally heavy minerals form concentrations and placers, few centimetres thick but rather continuous laterally. They are particularly widespread in the middle member of the formation.

e) *Lithic fragments*. They reach 15 % of the clasts in subfeldspathic and feldspathic sandstones. In sublithic and lithic facies they vary from 8 to 24 % and from 25 to 35 %, respectively. They are represented mainly by low metamorphosed and granitic rocks. Volcanic rocks are subordinate.

2. - Matrix and cement.

The matrix contained in the sandstones of the Formation reaches on the average a content of about 15 % of the rock with a maximum of 25 %. It consists of an extremely fine yellow or yellow-brown sericite-clay aggregate, partially recrystallized. The matrix occupies the pore spaces and occurs as films around the clasts, which in places are replaced along boundaries.

Siliceous cement is less abundant and occurs generally in the coarse-grained sandstones in amounts not higher than 10 % of the rock. It fills pore spaces and often forms quartz overgrowths on quartz clasts.

Another type of cement occurring in subordinate amounts is a haematitic cement which is often associated with placers of heavy minerals.

Petrological features previously described of the sediments of the lower member of the Lansdowne Arkose, show an alluvial plain environment of deposition evolving towards the top (silty beds) into a swampy flood plain.

The middle member also shows the same characteristics.

On the contrary, the sediments of the upper member show petrological features indicating a higher energy environment, similar to those of piedmont type. Sporadic aeolian episodes are interbedded throughout the Formation.

The very low textural and mineralogical maturity of the sandstones of the Formation indicates that they derived mainly from a nearby granitic and metamorphic basement, whilst the volcanic source is minor.

In the microconglomeratic lenses and horizons locally occurring within the Formation, the pebbles are mostly derived from the underlying sediments, particularly from those of the O'Donnell Formation.

The *Luman Silstone* represents the topmost formation of the Speewah Group. Its relationship with the overlying King Leopold Sandstone (Kimberley Group) seems to be conformable.

Still local unconformities are observed.

The thickness of the formation is variable, up to 50-60 meters.

The observation of the sequence is very difficult and uncertain, because of its extreme erodibility and the large amount of rubble from the overlying King Leopold Sandstone.

The formation is essentially silty and clayey. Towards the top of the sequence the silty character increases. Locally the siltstones grade into subfeldspathic and feldspathic fine grained sandstones. The sediments are mostly gray and gray-red in colour.

Texturally and compositionally they are very similar to those already described in the Valentine Siltstone, but they are somewhat more clayey.

The lack of sufficient field observations and petrographic studies on the sediments of Luman Siltstone does not allow a precise definition of their sedimentological and environmental features. Nevertheless, the macro and micro-characters of some samples of the Luman Siltstone are so similar to those of the Valentine Siltstone that it seems that both the Formations have the same depositional environment.

Kimberley Group

The *Pentecoste Sandstone* represents the topmost formation of the Kimberley Group. It lies conformably on the Elgee Siltstone and is in turn overlain conformably by the Hilfordy Formation of the Crowurst Group. The formation covers almost the entire central-western part of the area into consideration, cropping out continuously in an area about 90 km long and 30 km wide.

The maximum thickness of the formation reaches 500-550 meters in the central part of the area. Laterally the formation has been partially removed by erosion.

The Pentecoste Sandstone consists of three members cropping out over the whole area and easily recognizable in the field on the basis of their lithological features (figs. 2, 7, 8).

The lower member ranges from 50 to 120 meters in thickness. It consists of pink and reddish quartz-sandstones (50 %), and subfeldspathic and feldspathic sandstones (40 %). Sublithic sandstones are frequent (10 %) particularly at the base of the member (fig. 8).

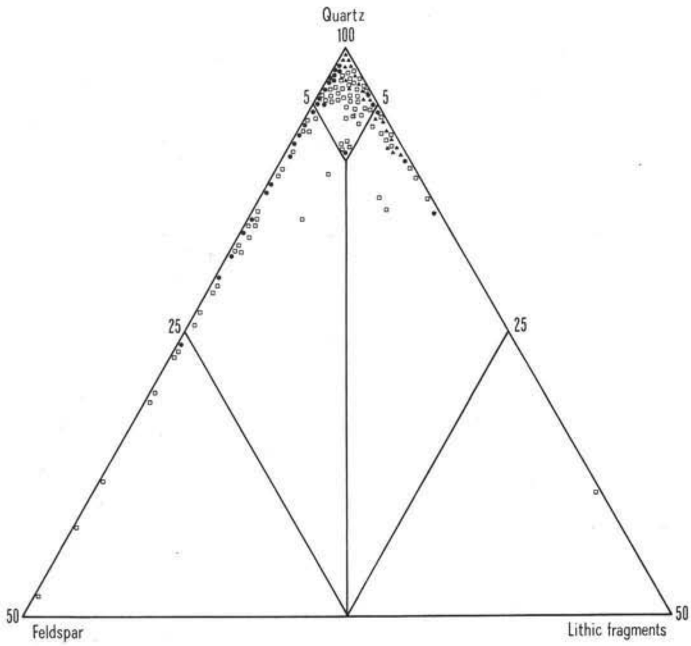

Fig. 8. — Classification of the sandstones of the Pentecoste Sandstone. (●) Lower member; (□) middle member; (▲) upper member.

The member terminates with a 20 meters thick horizon of mostly foliated reddish siltstones, cropping out on the whole area and representing a good marker bed.

The lower member shows regular bedding ranging from some centimetres to some decimetres in thickness.

Sedimentary structures are common and are represented by planar and trough cross-bedding in decimetre-thick sets, symmetrical and asymmetrical ripple-marks, current lineations (parting lineations, groove casts), mud-cracks and clay fragments. Rare convolute laminations can be observed.

The sandstones are generally fine-grained, but sporadic medium and coarse-grained facies occur. Sorting is moderate at the base of the member and good towards the top. Bimodal facies occur. The clasts are generally subangular to subrounded. Sphericity ranges from rather poor to good.

Texturally these sandstones can be classified as submature to mature from the base to the top of the member.

From mineralogical point of view the sandstones are composed of:

1. - Detrital components. Their content varies from 65 to 85 % of the rock.

   a) *Quartz*. It represents on the average 95 % of the clasts in quartz-sandstones, 90 % in sublithic sandstones and varies from 75 to 94 % in subfeldspathic and feldspathic ones (fig. 8). It is mainly granitic and catametamorphic (up to 97 %). Volcanic quartz occurs in a lesser amount (3 %, only in places 10 %); epimetamorphic quartz is rare.

   b) *Feldspar*. Rare in quartzsandstones, it may vary from 6 to 20 % of the clasts in subfeldspathic facies and from 26 to 48 % in feldspathic ones.

   c) *Micas*. They occur in very small quantities (1-2 %) and reach 5 % only in some feldspathic sandstones. Muscovite is much more diffuse than chloritized biotite.

   d) *Accessory minerals*. They are represented by red or pink zircon, blue and green tourmaline, green thorite, leucoxene and opaques. In some basal beds thin lenses of tourmaline, zircon and other heavy minerals occur. In some quartz-sandstones with haematitic cement, tourmaline can reach a content ranging from 1 % to 5 % of the rock.
   The ZTR index (Pettijohn, Potter & Siever, 1972), shows low to high values in different samples and an undifferentiated distribution from the base to the top of the sequence.

   e) *Lithic fragments*. They are not widespread in the basal member, ranging from about 6 % up to 15 % of the clasts in sublithic facies. Locally in some basal beds they reach 10-25 % of the rock. The fragments are mainly microcrystalline cherts, fine-grained quartzites, silty sandstones, haematitic shales, haematitized glauconite and acid volcanics.

2. - Matrix and cement. In the subfeldspathic and sublithic sandstones a sericite-clay matrix with fine disseminated haematite and limonite occurs with an average of 5-10 % of the rock. Locally it reaches 25 %. Allotriomorphic glauconite, associated with sericite-clay matrix, occurs rarely in pore spaces. In the quartz-sandstones there predominates a siliceous cement as overgrowths of quartz around the clasts or filling of pore spaces. Pressure solution phenomena are very common. The content of this kind of cement varies from a few per cent to 10-15 % of the rock.
   In some basal beds the cement is mostly haematitic.

The middle member of the Pentecoste Sandstone reaches the maximum thickness of 400 metres in the central part of the studied area. Its lower limit is defined by the silty band of the lower member. The upper limit, morphologically evident, coincides with a sharp gradation from fine grained lithic sandstones to coarse-grained and/or pebbly sandstones.

The middle member is composed mainly of quartz-sandstones (45 %) predominating in the lower portion of the sequence, of subfeldspathic and feldspathic sandstones (40 %) particularly widespread in the upper part and of subordinate sublithic sandstones (15 %) (fig. 8). The colour of these sediments varies from prevailing red to pinkish-white or gray-green.

Within the sequence there occur horizons of silty sandstones and foliated siltstones, several decimetres thick. The subfeldspathic and feldspathic portion of the member is represented by yellowish-red massive sediments showing a characteristic « earthy » nature and friability due to alteration into clay minerals of the feldspars.

The lower part of the middle member is characterized by a regular bedding. The upper part is composed of massive one metre thick layers interbedded with regular bedded horizons.

Sedimentary structures are very irregularly distributed within the sequence. Generally, in such structures the middle member is poorer than the lower one. Nevertheless, in fine grained sediments there is cross-bedding of the tabular and trough types and rarely of the herring-bone type in one decimetre thick sets. Symmetrical and asymmetrical ripples-marks, current lineations, mud-cracks, and pellets are also observed. The sandstones of this member are mainly fine grained (0.06-0.12 mm). Medium and coarse grained sediments are very subordinate.

Sorting is generally good or very good in quartz-sandstones in which bimodal textures are often common, particularly in the lower-middle part of the member. Sorting is lower in subfeldspathic facies. Roundness and sphericity show the highest values in quartz-sandstones, in feldspathic ones they are low or moderate. In the bimodal facies, the coarse-grained fraction generally shows higher values of roundness, sphericity and sorting than the fine fraction.

The textural maturity of the quartz-sandstones is thus high and very high, whilst the feldspathic sandstones are mostly immature and submature.

From a mineralogical point of view the sandstones are composed of

1. - Detrital components. Their content varies from 75 % to 80 % of the rock.
   a) *Quartz*. In the quartz-sandstones it reaches 98 % of the clasts. In subfeldspathic and feldspathic sandstones its average content is 85 % and 65 % of the clastic fraction respectively. In sublithic facies it averages 90 % (fig. 8). It is mainly granitic and catametamorphic. Volcanic quartz is less than 5 %, rarely reaches 10 % of the quartz fraction.
   b) *Feldspar*. In subfeldspathic and feldspathic sandstones it averages 15 % and 35 % of the clasts respectively. In quartz-sandstones and sublithic ones it can

reach sporadically 5 % of the clasts. Oligoclase and microcline are predominant. Orthoclase is subordinate. Feldspar is generally widely altered to clay minerals and haematitized.

c) *Micas*. They are rare and occur only in some fine silty sediments, where they may reach 1 %. Muscovite is more abundant than chloritized and glauconitized biotite.

d) *Accessory minerals*. Zircon, green tourmaline, thorite, apatite, leucoxene and other opaque minerals are observed. The ZTR index is generally high. In some fine feldspathic and more « earthy » horizons, the ZTR index can be very high.
Zircon and tourmaline are often concentrated in thin parallel placers.

e) *Lithic fragments*. Their content varies from 6 % to 12 % of the clasts in sublithic sandstones. In quartz-sandstones and subfeldspathic ones they can reach sporadically 5 % of the clasts.
They are mainly represented by haematitic shales, cherts, siltstones and fine quartz-sandstones. Fragments of micaceous quartzites, epidotic rocks and poikilitic quartz-muscovite aggregates of probable granitic origin are also present.

2. - Matrix and cement. In feldspathic and subfeldspathic sandstones matrix can reach 10-15 %, occasionally 20 % of the rock and is represented by a microcrystalline aggregate of sericite, clay and silica, often derived from alteration of feldspar. Haematite and limonite are widespread as fine disseminated fraction, particularly abundant in « earthy » horizons.

In fine-grained subfeldspathic facies rich in haematitic cement there occur glauconite pellets, showing accretion structures and often replacing the clasts, the matrix and silica cement of the rock. They are often associated with pyrite spherules in quartz-sandstones. These pellets are related to diagenetic processes following the compaction of the rocks.

In some micaceous beds glauconite occurs as free-form material filling pore spaces together with clay-sericite matrix. This kind of glauconite seems to be primary and related to the alteration of biotite flakes. Glauconite pellets showing clastic features also occur.

The cement of the quartz-sandstones, reaching on the average 5-10 % of the rock, consists mainly of quartz fillings in pore spaces and quartz overgrowths on clasts. In places the quartz grains with their overgrowths show in turn a clastic character. It is likely they represent fragments of re-cycled sediments (2^{nd} cycle sediments).

In the quartz-sandstones there are more or less oxidized pyrite spherules corroding and replacing the matrix and the clasts.

The « spherulitic » and « pellettoidal » facies described above are characteristic of the sediments of the middle member of the Pentecoste Sandstone, although

they have been sporadically observed in the upper part of the lower member.
The upper member of the Pentecoste Sandstone crops out in isolated strips, as relics of a sequence almost entirely destroyed by erosion, in the central-southern and western part of the area. The maximum thickness observed is about 125 meters. The upper member is composed mainly of quartz-sandstones (60 %) and subordinate sublithic sandstones (40 %) (fig. 8). Within the sequence, bands and lenses of microconglomeratic and pebbly sandstones occur. The colour of the sediments is from white to gray, with pink-reddish bands.
Rather regular bedding occurs in 50-60 centimetres and occasionally a metre thick layers. In the conglomeratic sandstones it is less evident.
Sedimentary structures are not widespread. The most frequent are: medium-size tabular and trough cross-bedding, in decimetres or rarely one metre thick sets, symmetrical and asymmetrical ripple-marks, rare mud-cracks and haematite pellets.
The conglomeratic lenses and horizons consist of a coarse grained quartzose matrix containing isolated pebbles (10-30 %) in places prevailing (50-60 %) on the matrix.
The pebbles vary from 1 to 10 centimetres and show generally good roundness and sphericity. They show also a quite irregular distribution pattern and chaotic orientation. In some places they may show fair embrication structures.
The sediments of the upper member are generally coarse-grained (0.5-2.0 mm). Medium or fine-grained facies are rare.
Sorting varies from moderate to good. Bimodal facies are present, but less common than in middle member. The clasts are commonly subrounded to rounded. Sphericity is for the most part good. Texturally the sandstones are mature and supermature.
From a mineralogical point of view the sublithic sandstones and the quartz--sandstones show a maturity respectively moderate and high or very high. They are composed of:

1. - Detrital components. Their content averages 92 % of the rock.
   a) *Quartz*. It represents on the average 98 % of the clasts in quartz-sandstones and 80 % in sublithic ones (fig. 8). It occurs as granitic and catametamorphic (60 %), epimetamorphic (up to 30 %) and volcanic quartz (up to 10 %).
   b) *Feldspar*. It is distributed in very small amounts (2-3 %) or it is absent. It consists mainly of albite and microcline. The presence of other K-feldspars is uncertain.
   c) *Micas*: are scarse to absent and consist generally of muscovite.
   d) *Accessory minerals*: zircon, large clastic fragments of green tourmaline, apatite, thorite and opaque minerals, occur. The ZTR index is low to medium.
   e) *Lithic fragments*. They represent up to 10 % of the clasts in sublithic facies

and are related to fine quartzites, haematitic siltstones, cherts and shales. In the conglomeratic sandstones pebbles are represented by subfeldspathic sandstones, fine quartzites, cherts and medium-grained quartz-sandstones.

2. - Matrix and cement. Content of matrix is very low, reaching 2-3 % of the rock. Matrix is represented by microcrystalline clay-sericite material filling pore spaces. A silica-sericite cement is more widespread (5 %). Haematitic cement occurs locally in nests and pockets.

The petrological features of the sediments of the lower member of the Pentecoste Sandstone seem to indicate an alluvial plain depositional environment, evolving towards the top to a swampy flood plain type (topmost silty horizons). Sporadic bimodal facies could be related to stages of aeolian reworking. Some quartz-sandstones, occurring at the base of the member, containing haematite cement and glauconite pellets, showing oolitic structures could be related to paralic environments.

The sediments of the middle member show the same features of predominantly alluvial plain environment with repeated aeolian stages and paralic episodes.

The upper member of the formation is characterized by a more turbolent fluviatile environment of the piedmont type.

Concerning the provenance of the clasts, there is evidence that in the lower member and in the lower portion of the middle one the volcanic and metamorphic sources are very subordinate. Clasts and fragments are mainly represented by 2nd cycle sediments and derived mainly from erosion of pre-existing sedimentary formations.

Passing from the lower to the upper part of the middle member, a rather sharp change in mineralogical composition can be observed. From quartz-sandstones the sediments grade into feldspathic and subfeldspathic facies, assuming therefore a more decisive « crystalline » character, related to a granitic source.

During the sedimentation of the upper member the clasts and the fragments derived from both igneous-metamorphic and pre-existing sediments.

Paleogeographic evolution

A great number of sedimentary structures indicating the current directions have been measured in the sediments of the Speewah Group and Pentecoste Sandstone. These measurements, carefully prepared and grouped according to the stratigraphic units of each formation described, have permitted a general paleocurrent analysis (POTTER & PETTIJOHN, 1963).

Paleocurrent diagrams of the Speewah Group (fig. 9) show current dispersion within a field of about 120-150° and a strongly preferred direction that is practically identical for the whole group. In the eastern part of the area this preferred direction is to S-SW, whilst in the central-western part, it diverts towards W.

The trend of the paleocurrents seems to indicate that the deposition of the sediments of the Speewah Group continued to be rather regular and uniform from the bottom to the top of the Group and took place in an alluvial plain fed by a meandering river running from N and NE to SW and W.

Paleocurrent diagrams of the three members of the Pentecoste Sandstone (figs. 9, 10, 11) show a current dispersion field of up to 150°, nevertheless a mean prevailing direction is always observed.

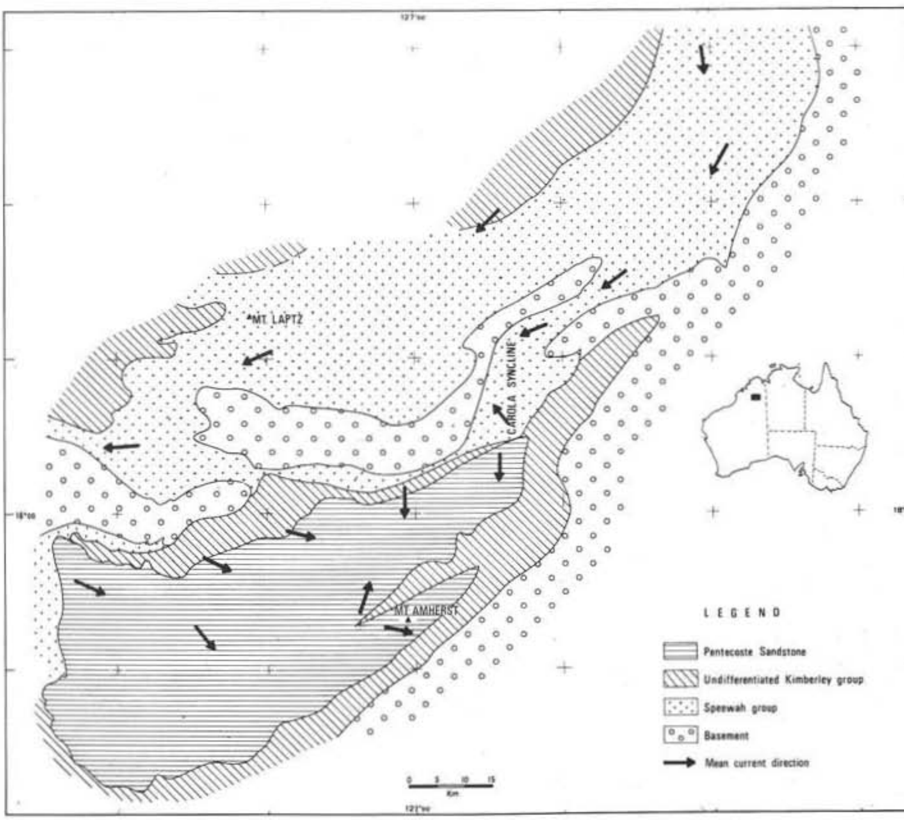

Fig. 9. — Mean current directions of the Speewah Group and of the lower member of the Pentecoste Sandstone.

In the lower member the paleocurrents show flow directions towards S and SE in the eastern part of the area, whilst in the western part a flow direction towards ESE and SE prevails.

In the middle member in the eastern part of the area the flow directions continue to indicate a general trend towards SE, whilst in the western part they divert towards WSW along the northern border of the basin and towards NW along the southern one (fig. 10).

In the upper member the paleocurrents show flow directions towards SW and WNW over the whole area (fig. 11).

One can observe therefore that during the sedimentation of the middle member of the Pentecoste Formation the paleocurrents began to divert from SE towards NW and WSW only in the western part of the basin. This variation involved the whole basin during the sedimentation of the upper member of the formation.

The deviation of the paleocurrents previously described may be due to a tectonic

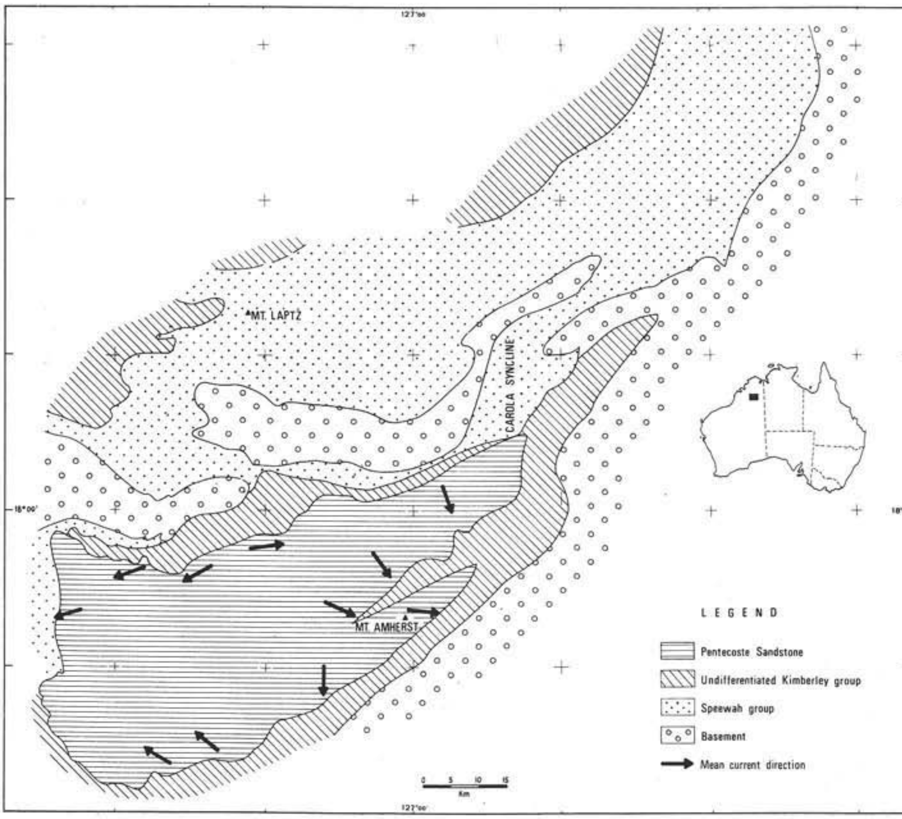

Fig. 10. — Mean current directions of the middle member of the Pentecoste Sandstone.

event which may have uplifted the eastern border of the basin. Such a movement began in the central part of the basin during the sedimentation of the middle member and extended towards the E during the deposition of the upper member.

The assumption that a tectonic event occurred, is supported also by the sharp compositional variation previously described which can be observed passing from the sediments of the lower member to those of the middle one. The remarkable enrichment in feldspars of the sediments of the middle member, attesting their more « crystalline » nature, could indicate a rejuvenated basement as source rock.

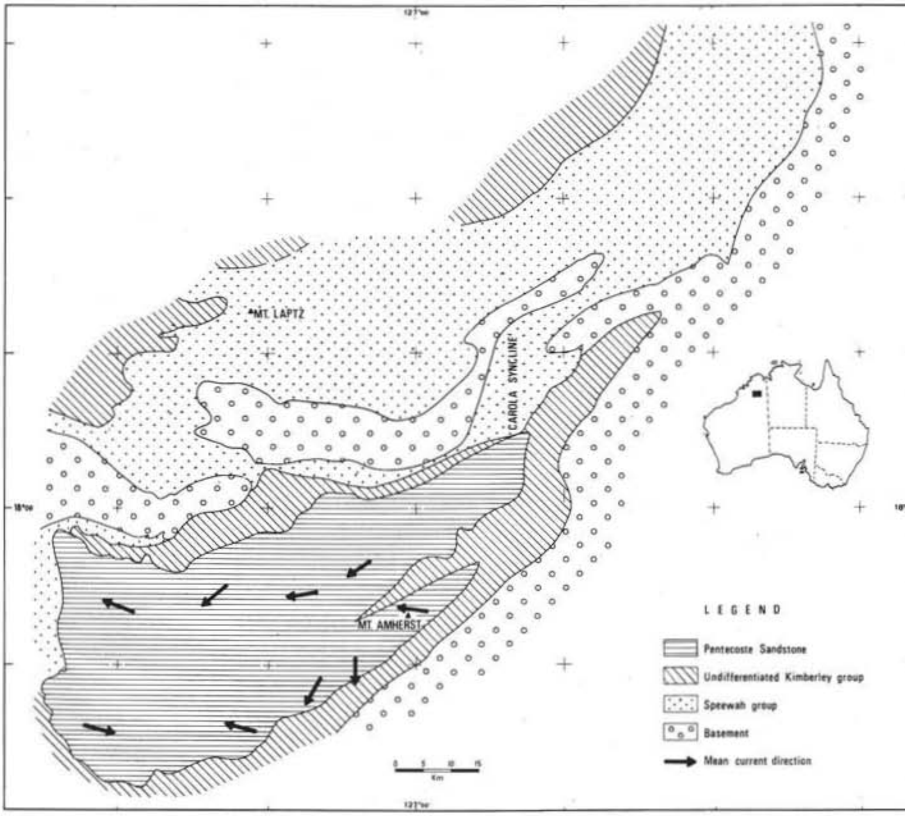

Fig. 11. — Mean current directions of the upper member of the Pentecoste Sandstone.

Conclusions

Detailed petrological investigations on the clastic formations of the Speewah Group and on the Pentecoste Sandstone (Kimberley region, Western Australia), enabled some deductions on their depositional environments and the paleogeographic evolution of their basins to be made.

The O'Donnell Formation is characterized by two fluviatile cycles of sedimentation: they evolve from an alluvial plain environment (lower arenaceous member) to a flood plain environment (silty member). The sediments are mainly composed of material derived from an acid volcanic substratum.

The Tunganary Formation was deposited on a braided alluvial plain and its sediments are composed mainly of acid volcanic material and to a lesser extent, of granitic-metamorphic rocks.

The Valentine Siltstone is characterized by a swampy flood plain environment and derived mainly from erosion of granitic rocks.

The Lansdowne Arkose sediments were deposited mostly in a fluviatile environment, evolving from an alluvial plain type with swampy flood plain stages to a piedmont type. The sediments of the formation are mainly derived from the erosion of a granitic basement and sedimentary formations.

The Pentecoste Sandstone sediments were deposited mainly in an alluvial plain environment, evolving towards the top in a piedmont type. Within the sequence, sediments characterized by swampy flood plain and paralic environments occur.

In the above described formations sediments of aeolian environment area often observed.

Paleocurrent analysis allowed a definition of the paleogeographic evolution of the sedimentation basins of the formations taken into consideration. The deposition of the Speewah Group was rather regular and uniform from the bottom to the topmost formation and was fed by a river running from N and NE to W to S and from NE to SW.

The Pentecoste Sandstone shows, on the contrary, a deviation of flow directions from the base to the top of the sequence. They divert from S and SE towards W and NW. This deviation may be related to a tectonic event that rejuvenated the crystalline basement.

REFERENCES

ANDEL VAN T. H. (1958) - *Origin and classification of Cretaceous, Paleocene and Eocene Sandstones of Western Venezuela.* A.A.P.G. Bull., 42, 734-763.

BURST J. F. (1958) - *« Glauconite » pellets: their mineral nature and applications to stratigraphic interpretations.* A.A.P.G. Bull., 42, 310-327.

DOW D. B., GEMUTS I. (1967) - *Dixon Range, W.A. - 1:250,000 Geological Series.* B.M.R. Aust. Explan. Notes, SE/52-6.

DOW D. B., GEMUTS I. (1969) - *Geology of the Kimberley Region, Western Australia: The East Kimberley.* B.M.R. Aust. Bull., 106.

EDWARDS A. B. (1943) - *Some basalts from the North Kimberley, Western Australia.* J. Roy. Soc. W. Aust., 27.

GELLATLY D. C., DERRICK G. M. (1967) - *Lansdowne, W.A. - 1:250,000 Geological Series.* B.M.R. Aust. Explan. Notes, SE/52-5.

GUPPY D. J., LINDNER A. W., RATTIGAN J. H., CASEY J. N. (1958) - *The Geology of the Fitzroy Basin, Western Australia.* B.M.R. Aust. Bull., 36.

HARDMAN E. T. (1885) - *Report on the geology of the Kimberley District, Western Australia.* W. A. Parl. Pap., 34.

HARMS J. E. (1959) - *The geology of the Kimberley Division, Western Australia, and of an adjacent area of the Northern Territory.* M. Sc. Thesis, Adelaide Univ. (unpublish.).

KRYNINE P. D. (1946) - *Microscopic morphology of quartz types.* Anais do Segundo Congresso Panamericano de Engenharia de Minas e Geologia, vol. III, 2ª Commissao, Geologia, Paleontologia, Mineralogia e Petrologia.

MAITLAND A. G. (1928) - *The volcanic history of Western Australia.* J. Rev. Soc. W. A., 13, 79-86.

MATHESON R. S., GUPPY D. J. (1949) - *Geological reconaissance in the Mount Ramsay area, Kimberley Division, Western Australia.* B.M.R. Aust. Rec. 1948/49 (unpublished).

PETTIJOHN F. J. (1949) - *Sedimentary rocks.* Harper and Brothers Publishers, New York.

PETTIJOHN F. G., POTTER P. E., SIEVER R. (1972) - *Sand and sandstones.* Springer-Verlag, Berlin.

POTTER P. E., PETTIJOHN F. J. (1963) - *Paleocurrents and basin analysis.* Springer-Verlag, Berlin.

ROBERTS H. G., HALLIGAN R., PLAYFORD P. E. (1958) - *Mount Ramsay, W. A. - 1:250,000 Geological Series.* B.M.R. Aust. Explan. Notes SE/52-9.

TAKIHASHI J. (1939) - *Synopsis of glauconitization.* In Trask P.D. Ed. Recent Marine Sediments. Tulsa, Oklahoma, A.A.P.G., 503-513.