6. THE GEOLOGY OF THE URANIUM DEPOSITS

In this section the geological characteristics of the actual mineralized areas of the uranium ore deposits are discussed.

6.1 Deposits in the Gawib River Valley

Percussion drilling has been the main technique used in evaluating the ore-body. The resultant powders were radiometrically logged in the field using a calibrated scintillometer. Based on this information, the shape and nature of the ore-body was deduced. Unfortunately adequate sampling during percussion drilling is impossibe below the water-table. Thus, a complete assessment of the characteristics of the ore-body was limited and all information obtained concerned the upper portions only. It is known, however, that carnotite extends below the water-table.

Initially a few conventional boreholes were drilled but proved unsatisfactory due to a very poor core recovery. A comparison of the $CaCO_3$ values of the powders from the boreholes (Table 27) reveals the presence of as little as 2 to 9 per cent $CaCO_3$. This would account for the bad core recovery. In places the calcrete is therefore only partially consolidated and has a structure similar to that shown in Plate 12.

Radiometric logs of the percussion borehole powders provided data for the construction of profiles depicting the shape, size and general morphology of the ore-body. Fig. 8

gives a selection of profiles drawn by General Mining and Finance Corp. Ltd showing the configuration of the ore-body at cut-off values of 100 ppm eU_3O_8.

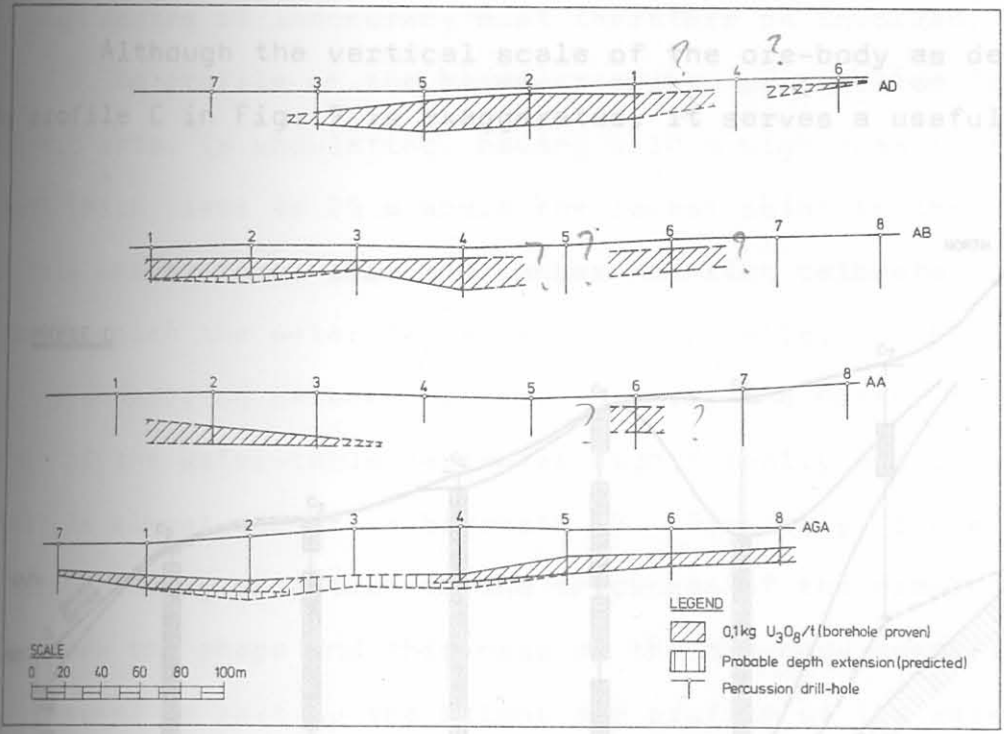

Fig. 8: Profiles of the uranium ore-body in the Gawib River Valley as determined from the radiometric logs of the percussion borehole powders. The outline of the ore-body includes all those values above 0,1 kg eU_3O_8/t or 100 ppm eU_3O_8.

Structurally, the ore-body has a tabular shape but does lack continuity. Boreholes 4 and 5, for example, in profiles AD and AB respectively, did not intersect mineralization, whereas adjacent boreholes did. In profile AA, ore was still being found at the water-table in boreholes 2 and 3. It is reasonable to assume that the uranium ore extends below the water-table. As a whole, the ore-body is undulatory as observed in profile AGA.

The ore-body is not homogeneous for there is segregation of the uranium ore into layers or pockets. This discontinuity of mineralization suggests a concretionary type of uranium accumulation.

Although the vertical scale of the ore-body as depicted by profile C in Fig. 9 is exaggerated, it serves a useful

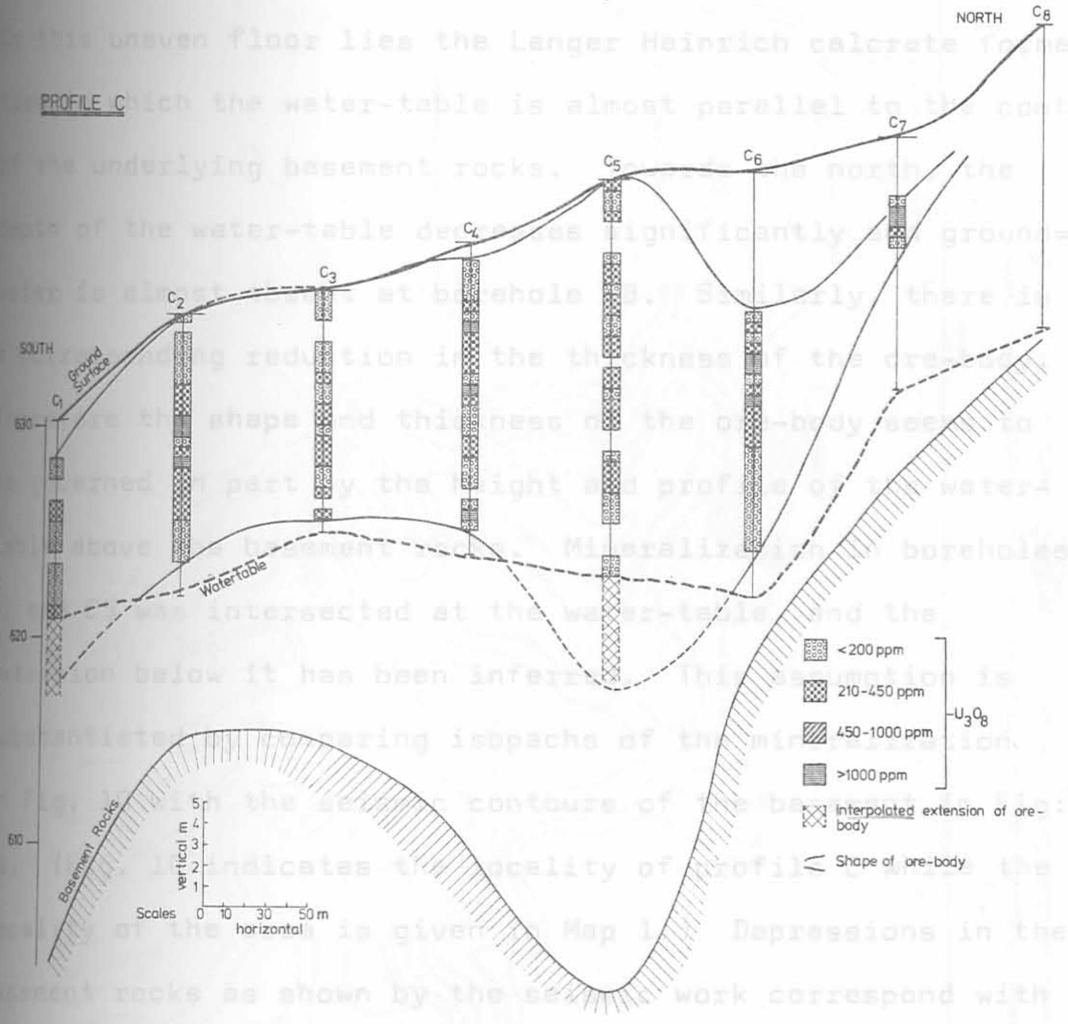

Fig. 9: A cross section of the ore-body through profile C which shows the relationships between the ore-body, water-table and basement rocks.

purpose to illustrate certain aspects. Boreholes C1 and C8 were drilled to the water-table. The definition of the water-table is rather arbitrary, as the site geologist regarded it as the point where the emerging powder became damp. A fair=ly high degree of inaccuracy must therefore be involved.

The profile of the basement rocks, as revealed from seismic data, is undulating, having a 10 m high hump to the south which rises to 25 m above the lowest point to the north. On this uneven floor lies the Langer Heinrich calcrete forma=tion in which the water-table is almost parallel to the contours of the underlying basement rocks. Towards the north, the depth of the water-table decreases significantly and ground=water is almost absent at borehole C8. Similarly, there is a corresponding reduction in the thickness of the ore-body. Therefore the shape and thickness of the ore-body seems to be governed in part by the height and profile of the water-table above the basement rocks. Mineralization in boreholes C1 and C5 was intersected at the water-table, and the extension below it has been inferred. This assumption is substantiated by comparing isopachs of the mineralization in Fig. 10 with the seismic contours of the basement in Fig. 11. (Fig. 10 indicates the locality of profile C while the locality of the area is given in Map 1.) Depressions in the basement rocks as shown by the seismic work correspond with thicker mineralized areas, particularly in the area of profile C.

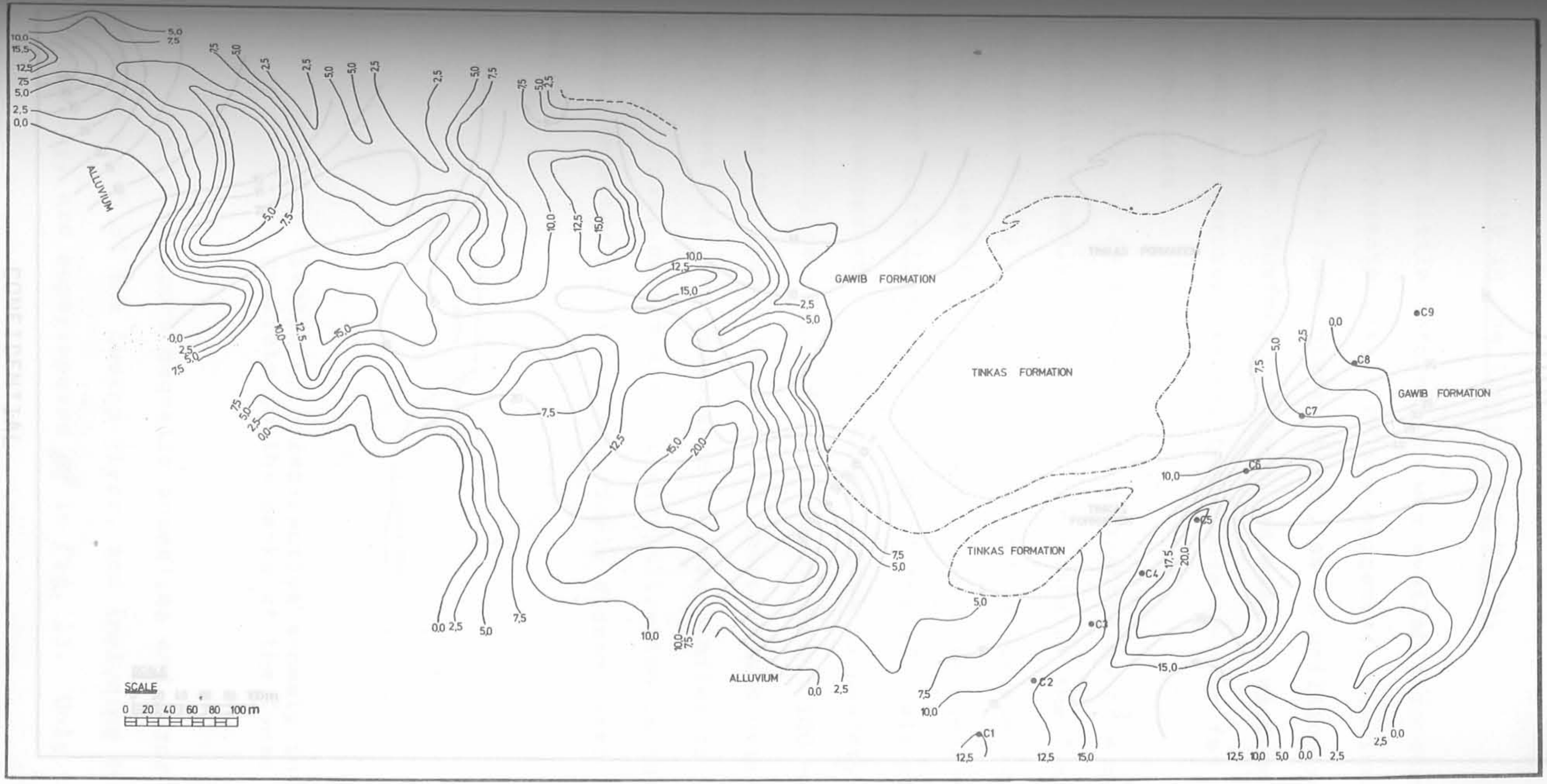

Fig. 10 A portion of the Langer Heinrich calcrete formation showing mineralization isopachs interpolated from percussion borehole data. Note position of profile C. (Compiled from maps of General Mining and Finance Co. Ltd.)

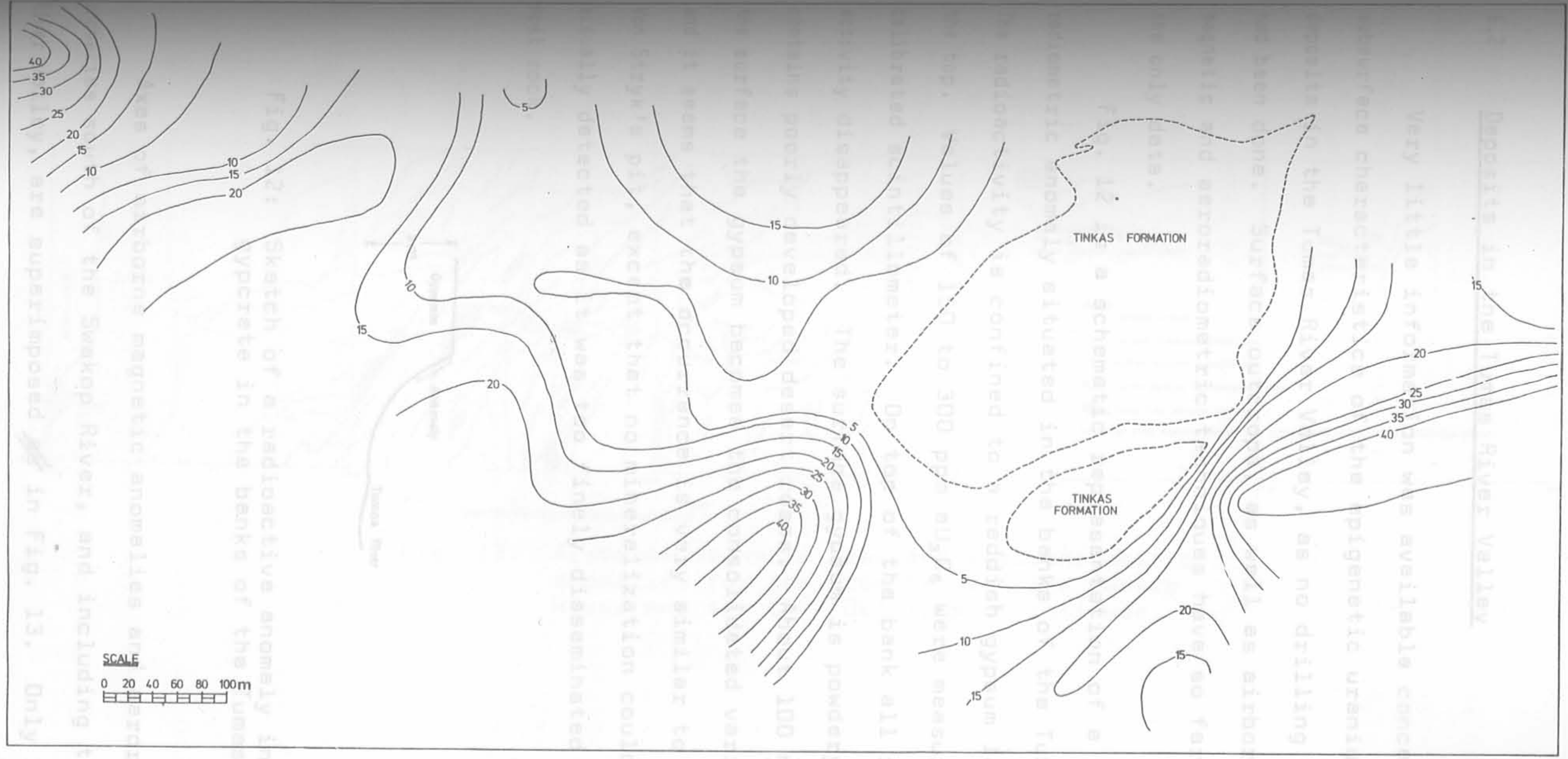

Fig. 11 Seismic isopachs interpolated from seismic refraction data of the same locality as in Fig. 10. (Compiled from maps of General Mining and Finance Co. Ltd.)

6.2 Deposits in the Tumas River Valley

Very little information was available concerning the subsurface characteristics of the epigenetic uranium ore deposits in the Tumas River Valley, as no drilling work had been done. Surface outcrops, as well as airborne magnetic and aeroradiometric techniques have so far provided the only data.

Fig. 12 is a schematic representation of a surface radiometric anomaly situated in the banks of the Tumas River. The radioactivity is confined to a reddish gypsum layer near the top. Values of 150 to 300 ppm eU_3O_8 were measured by calibrated scintillometer. On top of the bank all radio=activity disappeared. The surface gypsum is powdery and contains poorly developed desert roses. About 100 mm below the surface the gypsum becomes the consolidated variety, and it seems that the occurrence is very similar to that in Von Stryk's pit, except that no mineralization could be visually detected as it was too finely disseminated in the host rock.

Fig. 12: Sketch of a radioactive anomaly in the gypcrete in the banks of the Tumas River.

Axes of airborne magnetic anomalies and aeroradiometric anomalies south of the Swakop River, and including the Tumas River Valley, are superimposed ~~as~~ in Fig. 13. Only the

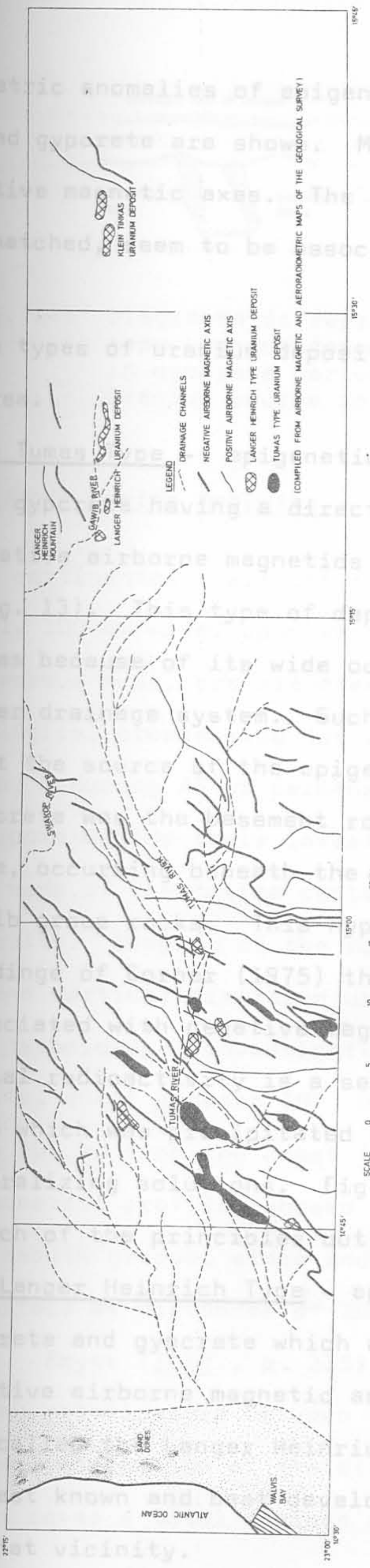

Fig. 13: Airborne magnetic axes and aeroradiometric anomalies for the area between the Swakop River and the 23° 00' line of latitude.

aeroradiometric anomalies of epigenetic origin situated in calcrete and gypcrete are shown. Most of the anomalies lie above negative magnetic axes. The remainder, those that are cross-hatched, seem to be associated with drainage channels.

Two types of uranium deposits are therefore indicated for this area.

(a) The Tumas Type - epigenetic deposits in calcrete and gypcrete having a direct relationship between negative airborne magnetics and aeroradiometrics (Fig. 13). This type of deposit is given the name Tumas because of its wide occurrence in the Tumas River drainage system. Such a relationship implies that the source of the epigenetic uranium in the gypcrete was the basement rocks, probably of alaskitic type, occurring beneath the superficial cover of the Namib group rocks. This hypothesis is based on the findings of Corner (1975) that the alaskites are associated with negative magnetic anomalies. Super=ficial radioactivity is a secondary uranium dispersion halo which was precipitated by upward migration of mineralizing solutions. Fig. 14 is a diagrammatic sketch of the principles outlined above.

(b) The Langer Heinrich Type - epigenetic deposits in calcrete and gypcrete which are not related to negative airborne magnetic anomalies. These deposits are called the Langer Heinrich Type because the largest known and best developed deposit is situated in that vicinity.

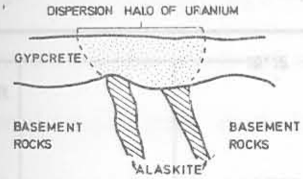

Fig. 14: Diagrammatic representation of a Tumas type uranium deposit. Epigenetic uranium in gypcrete derived from a primary uranium source in alaskites.

6.3 Offshore Marine Deposits

The continental shelf off the coast at Swakopmund is approximately 100 km wide, upon which a series of basins, filled with diatomaceous muds, are situated.

Geological prospecting for uranium in the basins was undertaken by Preussag AG of Germany, and Union Corporation Ltd. The purpose behind their investigation was to determine whether the muds of the basins contained economically viable uranium deposits. Mapping of the muds was done in both a horizontal and vertical direction using bathometric and echographic techniques. Investigations covered an area of the continental shelf between 19° 00' S to 25° 30' S and ranged up to 100 km from the coast (Meyer, 1973).

Bathometric profiles showed that the continental shelf has a smooth gradual slope and lies between 50 and 150 m below the surface at distances of 10 and 70 km from the coast respectively. Meyer (ibid., p. 315) points out that there seems to be no relationship between the morphology of the shelf and the distribution of the diatomaceous mud. The muds in the basins cover a total surface area of 19 000 km² and have a maximum depth of about 15 m.

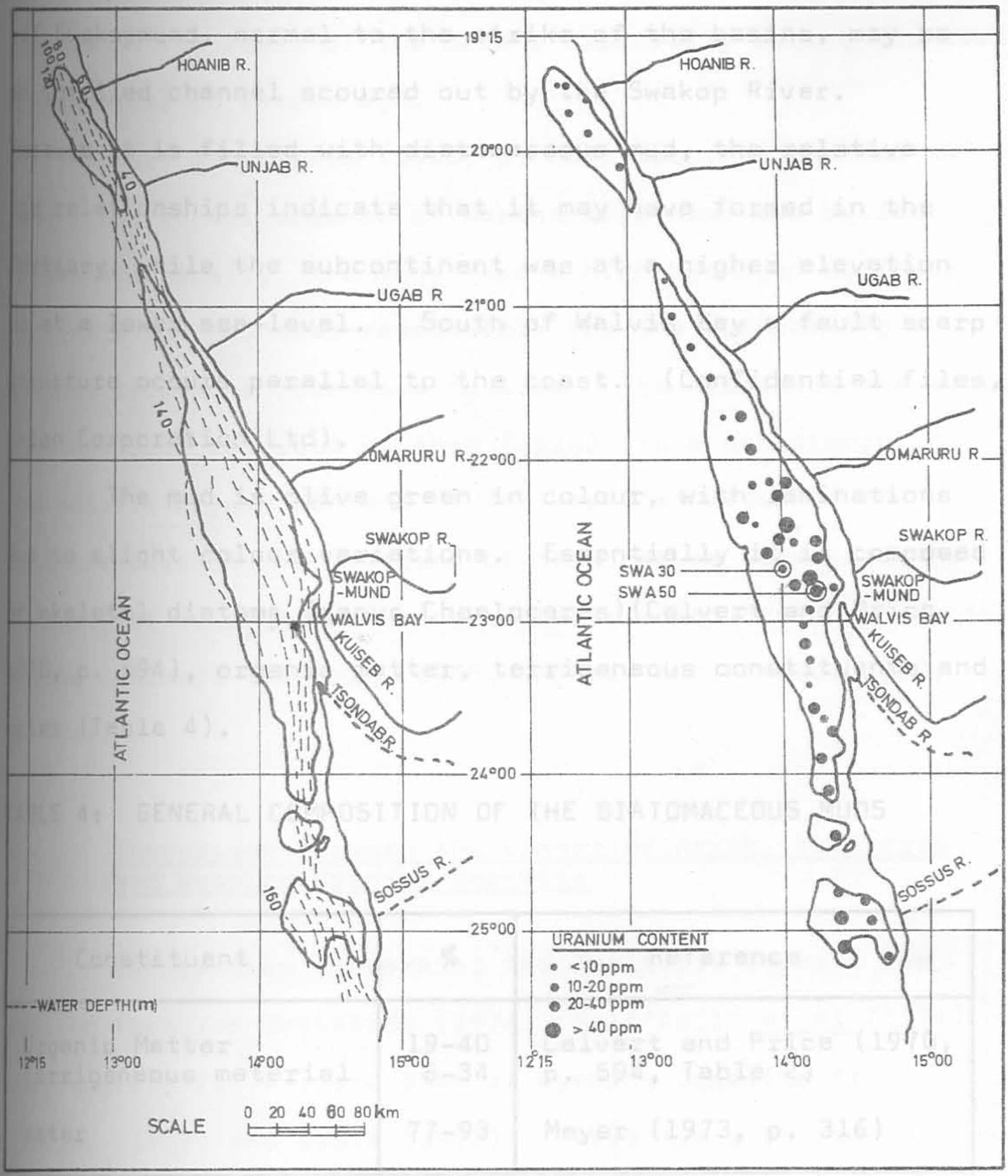

Fig. 15 Four anaerobic basins on the continental shelf which are filled with diatomaceous mud.
(a) Basins in relation to depth of water.
(b) The distribution of uranium in the basins.

Four basins have been recognized (Fig. 15), the largest of which lies between 21° 00' S and 24° 00' S, with its centre just off Swakopmund. A protrusion situated off Swakopmund, normal to the strike of the basins, may be an infilled channel scoured out by the Swakop River. Because it is filled with diatomaceous mud, the relative age relationships indicate that it may have formed in the Tertiary, while the subcontinent was at a higher elevation or at a lower sea-level. South of Walvis Bay a fault scarp structure occurs parallel to the coast. (Confidential files, Union Corporation Ltd).

The mud is olive green in colour, with laminations due to slight colour variations. Essentially it is composed of skeletal diatoms (genus Chaeloceras) (Calvert and Price, 1970, p. 594), organic matter, terrigeneous constituents and water (Table 4).

TABLE 4: GENERAL COMPOSITION OF THE DIATOMACEOUS MUDS

Constituent	%	Reference
Organic Matter	19-40	Calvert and Price (1970, p. 594, Table 2)
Terrigeneous material	6-34	
Water	77-93	Meyer (1973, p. 316)

Below the diatomaceous mud a silty to sandy layer was found in places but at other localities there is a fossil shell layer containing remains of gastropods, lamellibranchs and sharks' teeth (Meyer, 1973, p. 316).

Palaeontological investigations date the muds to be of Holocene age, but the lower fossil shell layer is late

Pleistocene. Relationships within the latter reveal glacial changes in the level of the ocean, especially during the last interglacial of Eemian age.

Hart and Currie (1960, p. 204) describe the mud as azoic, due to the absence of marine life near the bottom. Characteristically, the muds have a high hydrogen sulphide content which has been responsible for the suffocating gaseous eruptions from time to time. The origin of the azoic zone has been ascribed by them (ibid.) to a deficiency in the soluble oxygen content of the upwelled water of the Benguela Current. Conditions of this nature stimulate the activity of sulphate-reducing bacteria which have been found in the sediment (Baturin, 1949, in Hard and Currie, 1960, p. 204).

6.4 Comparison Between the Langer Heinrich, Yeelerrie and Wyoming Uranium Deposits

Information concerning the Yeelerrie deposit was derived from Von Backström (1974), Dall'Aglio et al (1974) and Langford (1974), and that of Wyoming deposits from Rackley (1972) and Grutt (1972). There are some fundamental similarities between the ore deposits mentioned which are worthwhile enumerating. These are listed in Tables 5 and 6.

Certain similarities between the Langer Heinrich and Wyoming uranium deposits are compared in Table 6. The major dissimilarity is, however, the nature of the diagenesis, for the former is a calcrete occurrence whereas the latter is mainly a sandstone with little calcite. Grutt (1972, p. 74) mentions that the location of calcareous concretions and calcareous cemented sandstones in relation to uranium deposits may be a possible exploration guide. As yet no such deposits have been reported in the USA.

TABLE 5: COMPARATIVE CRITERIA BETWEEN THE LANGER HEINRICH AND YEELERRIE URANIUM DEPOSITS

Comparative Criteria	Langer Heinrich Uranium Deposit	Yeelerrie Uranium Deposit
Age	(a) Calcrete - of the Langer Heinrich calcrete formation - Miocene to Pliocene	(a) Calcrete - Pliocene to nearly Pleistocene
	(b) Carnotite - Recent, 30 000 years.	(b) Carnotite - Pleistocene
Climate	Desert	Semi-desert
Host rock	Desert fluviatile breccia-conglomerate deposited in Gawib River, cemented with calcite. Grey to brown in colour	Detrital quartz and feldspar, clay and calcite forming low-level calcrete deposits along major drainage. Fine-grained and porcellaneous. Grey to brown colour
Provenance	Crystalline basement, quartzites, schists, granofels, granites and pegmatites	Basement rocks composed of granites and greenstones. Laterites
Stratigraphic features	(a) Sediments deposited on unconformity - African erosion surface - Cretaceous to Tertiary	(a) Sediments deposited on unconformity - Cretaceous to Tertiary

Comparative Criteria	Langer Heinrich Uranium Deposit	Yeelerrie Uranium Deposit
	(b) Epeirogenic uplift initiated new erosion cycle	(b) Epeirogenic uplift initiated new erosion cycle
Deposit type	(a) Tabular and concretionary, layers separated in places by barren zones	(a) Tabular, horizontal layers
	(b) Uranium occurs as fillings in pore spaces surrounding detrital grains	(b) Uranium occurs as irregular fillings in small fractures and cavities
Mineralization	Yellow to greenish carnotite	Yellow carnotite
Paragenesis	(a) Precipitated from subsurface water by soil suction and nucleation	(a) Precipitated from surface water by reduction in partial pressure of CO_2
	(b) Source of uranium and vanadium in basement rocks. Vanadium mainly from Tinkas Formation	(b) Source of uranium - granites. Source of vanadium - laterites
Associated elements	Uranium and vanadium	Uranium and vanadium
Environment	Oxidizing	Oxidizing

TABLE 6: COMPARATIVE CRITERIA BETWEEN THE LANGER HEINRICH AND WYOMING URANIUM DEPOSITS

Comparative Criteria	Langer Heinrich Uranium Deposit	Wyoming Uranium Deposits
Host rock	Fluviatile breccia-conglomerate derived from granite, quartzite and schist. Cemented by calcite. If calcite cement is removed a similar rock type as in Wyoming remains.	Fluviatile sandstones. derived from granitic rock, arkosic to subarkosic, medium-grained to conglomeritic, angular and poorly sorted. Limited calcite cement.
Depositional environment	The Langer Heinrich calcrete formation is a channel-type deposit and it is not unlikely that alluvial fans radiated from the Langer Heinrich Mountain during the upper Tertiary.	Sediments in the Gas Hills, Wind River Basin and West Shirley Basin were deposited in alluvial fans. In the East Shirley Basin sediments were deposited in channels and flood basins.
Structural and stratigraphic features	The uparched areas about the Gawib River are the Langer Heinrich Mountain and the Schieferberge, which are both structural orogenic features. Geomorphologically, the region has been subjected to successive uplifts.	Material was derived from uparched regions and deposited in adjoining intermountain areas.
Hydrodynamic environment	Carnotite precipitated along with the second generation calcite, possibly brought about by changing hydrodynamic conditions.	Following deposition of arkose, uplift changed the hydrodynamic conditions resulting in the onset of oxidizing conditions and carnotite precipitation.
Transportation	Migration of mineralization solutions is controlled by permeability of the host rock. Those sections with low calcite content were the best passageways.	Migration of mineralizing solutions is controlled by permeability within the host rock.

From the comparisons in Table 6 it is very clear that there are noticable similarities between the type of host rocks. The most outstanding and common feature is the necessity to have a continental breccia-conglomerate or poorly sorted sandstone-type rock formed in drainage channels which provide suitable passageways to mineralizing solutions. Also, it was the change in hydrodynamic condi= tions that brought about the precipitation of carnotite in both instances.