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The Mud Tank Carbonatite, Strangways Range, central Australia

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The Mud Tank Carbonatite at the eastern end of the Strangways Range, about 100 km northeast of Alice Springs, was the first to be recognised in Australia. Crystalline carbonate rocks containing apatite, magnetite and zircon occur in a northeast-trending zone about 2 km long and up to 700 m wide, and in a second, much smaller, lens about 2 km to the southwest. The rocks show banding, owing to differences in texture and composition, and can be broadly divided into crystalline carbonate rocks with subordinate apatite, magnetite, phlogopite, chlorite, and soda-amphibole; foliated micaceous carbonate rocks rich in pale brown phlogopite; and feldspathic carbonate rocks with various amounts of sodic plagioclase, clinopyroxene, green-brown amphibole, and brown biotite. This last group is considered to be largely of hybrid origin. Calcite and dolomite occur in various proportions in all the rock types. Country rocks are schists and gneisses of the Early Proterozoic Arunta Block. Trace element concentrations, particularly of niobium and rare earths, are within established ranges for carbonatites, but well below economic values. On the other hand, zircon crystals of gem quality are present in the soil and colluvium overlying the carbonatite, and vermiculitic mica has developed in the weathered zone within about 40 m of the surface.

Introduction

The Mud Tank Carbonatite is located at latitude 23°01'S longitude 134°16'E, about 100 km north-northeast of Alice Springs, (Fig. 1). Attention was first drawn to this locality through the presence of detrital magnetite, apatite, and zircon, which are widely scattered over the area underlain by the carbonatite. The occurrence was first described by H.B. Owen (1944), who examined it as a possible source of phosphate in 1944 and considered the carbonate rocks to be metamorphosed limestones. In 1966, the area was investigated by B.T. Williams of Geopeko Ltd, who mapped four areas of outcropping carbonate rocks and carried out a programme of four diamond-drill holes, totalling 350 m. In his account of the area, Williams (1967) briefly considered that some of the rocks could be carbonatites, but rejected the idea, mainly because of the prominent banding, which he regarded as relict bedding. P.W. Crohn first became interested in the area in 1967 after seeing a number of Canadian carbonatite complexes.

Following a preliminary account by Crohn & Gellatly (1969), a petrological study was undertaken by Gellatly (1969), and four more diamond-drill holes, totalling about 550 m, were drilled by the Mines and Water Resources Branch, Northern Territory Administration, in the same year (Crohn, 1971). Other recent investigations have included a regional gravity survey (Flavelle, 1965), and a low-level aeromagnetic survey (Tipper, 1966), both undertaken by the Bureau of Mineral Resources, age determinations by Black & Gulson (1978), and isotopic studies of the carbonate rocks by Moore & Grey (1973) and Wilson (1979). More recently, the area has again been under investigation by the Northern Territory Department of Mines and Energy to assess its economic potential as a source of vermiculite (D.H. Moore, in prep.).

Field occurrence

The main occurrence consists of an irregular northeast-trending lens of crystalline carbonate rocks, some 2 km long and from 200 to 700 m wide, which crops out intermittently in three low, gently sloping hills. A second, considerably smaller lens lies about 2 km to the west-southwest, (Fig. 2).

The carbonate rocks are highly altered and in part ferruginised at the surface. In places they show banding, owing to differences in texture and the content of non-carbonate minerals, mainly mica, magnetite, and apatite. The trend of the banding is generally northeasterly, parallel to the long axis of the occurrence and to the trend of the surrounding schists and gneisses. Individual bands range from a few centimetres to more than a metre in width.

Apatite generally occurs as massive aggregates, some of which are up to 60 cm across, and individual grains of more than 2 cm are not uncommon. Magnetite forms twinned octahedra up to 10 cm across and occasional larger aggregates. Mica generally occurs as plates up to about 2 cm across, and zircon as relatively squat prismatic crystals up to 5 cm long and 2 cm across.

Small lenses and irregular masses of amphibolite (soda-amphibole, biotite, minor plagioclase, diopside, calcite and dolomite) and sodic pegmatite (sodic plagioclase, biotite, soda-amphibole and/or aegirine-augite, minor calcite and/or dolomite), generally less than 3 m across, also occur within the carbonatite, but their contacts are not exposed.

The host rocks are schists and gneisses, calc-silicate rocks and basic igneous rocks of the Early Proterozoic Arunta Block. In places, these can be traced to within about 20 m of the carbonatite, but the actual contacts are not exposed, although they have been located approximately by auger drilling and intersected in two places by diamond drilling (Mines and Water Resources Branch diamond-drill holes A and B). In these drill holes, relationships at the major contacts are obscured by extensive shearing and associated weathering, but in DDH A there is a suggestion of minor occurrences (? veins) of carbonate rocks within the host rocks up to 25 m from the main contact. Very minor alteration of the gneiss has been recorded by Moore (1973), who noted the replacement of (?) aegirine by soda-amphibole for distances of up to 50 cm from the carbonate contact.

Magnetite-rich zones within the complex give rise to a number of distinctive magnetic anomalies of up to 1800 gammas, which indicate a steep north-westerly dip for the bodies responsible for them, in good agreement with observed dips on the layering of the outcropping carbonate rocks (Tipper, 1969).

Structural setting

The carbonatite lies on the axis of a major regional gravity high, which extends in a general east-west direction for at least 600 km, and includes the Papunya Gravity Ridge to the west and the Illogwa Gravity High to the east (Flavelle, 1965).

A major structural feature, the northwest-trending Woolonga Lineament, passes about 8 km southwest of the carbonatite.

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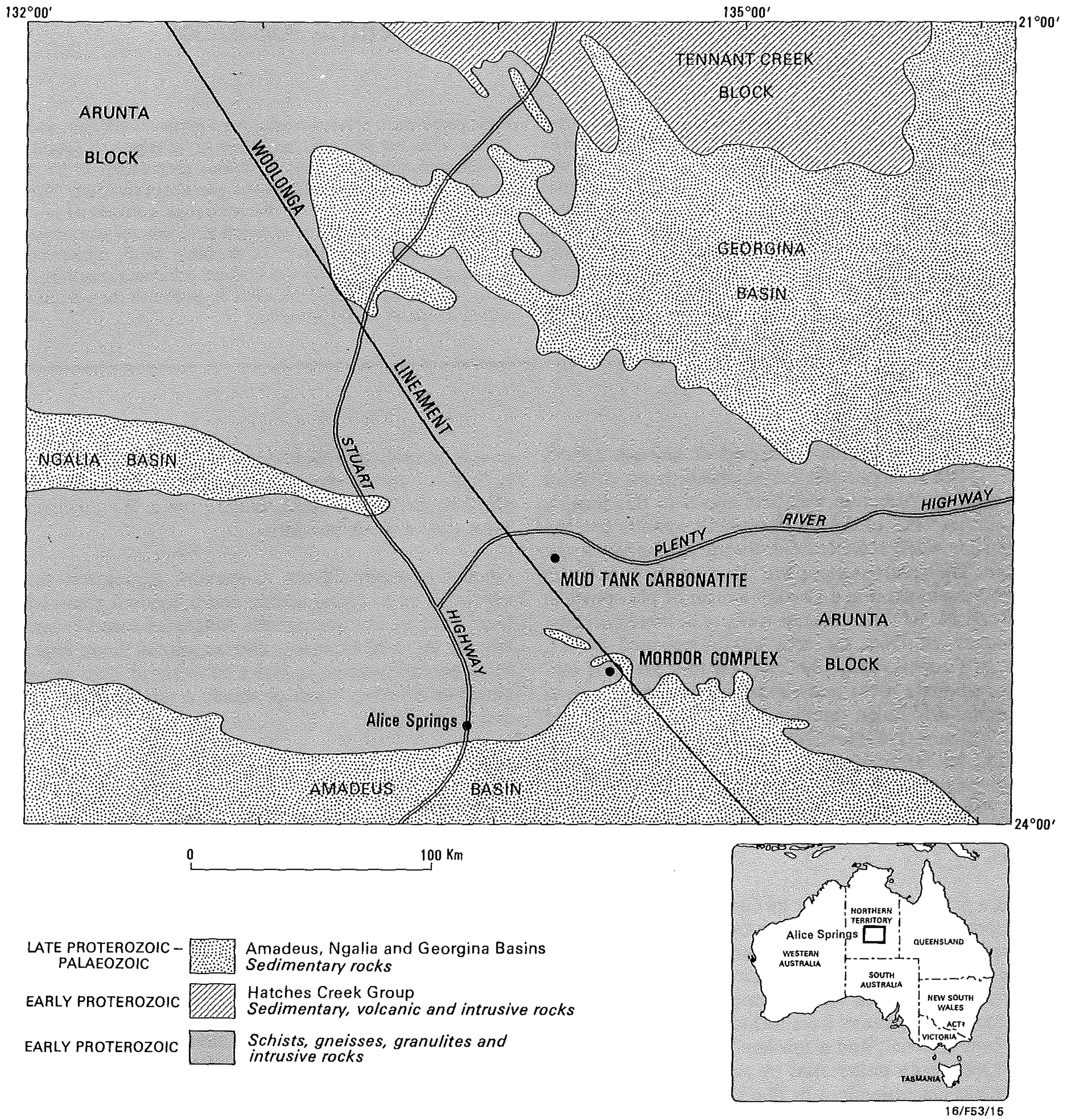

Figure 1. Regional geological setting, Mud Tank Carbonatite (based on BMR 1:2 500 000 geological map of the Northern Territory, 1976).

This also has been traced for several hundred kilometres, in part by its effect on the gravitational pattern, and may represent a deep-seated structural feature (Fig. 1) (Anfiloff & Shaw, 1973).

In the immediate vicinity of the carbonatite, the host rocks, mainly quartz-muscovite schists with minor garnet granulites and amphibolites, show some evidence of shearing and recrystallisation, suggestive of another shear zone with a northeasterly trend, parallel to the long axis of the carbonatite and complementary to the Woolonga Lineament. This may be a pre-carbonatite structure, which has partly controlled the emplacement of the carbonatite, with subsequent movement giving rise to shearing and faulting within the carbonatite and along its contacts with the host rocks. The largest fault cutting the carbonatite has an apparent displacement of about 300 m, east block north.

The Woolonga Lineament also passes close to another alkaline intrusion. The Mordor Complex (Langworthy & Black, 1978) is an alkaline ultramafic intrusion some 50 km southeast of the Mud Tank Carbonatite. This complex is cut by veins and small irregular masses of carbonates, suggesting possible carbonatitic affinities, but it has been dated at 1210 ± 90 Ma (Langworthy & Black, 1978) compared to 730 Ma for the Mud Tank Carbonatite (Black & Gulson, 1978).

Petrology

The rocks of the Mud Tank Carbonatite complex can be divided into a number of groups. Those most closely resembling typical carbonatites as recorded from other occurrences are crystalline carbonate rocks with subordinate apatite, magnetite, phlogopite, chlorite, and soda-amphibole, which are relatively abundant throughout the complex. Either calcite or dolomite may predominate, with the latter tending to form the larger grains (Gellatly, 1969). Ilmenite is commonly associated with the magnetite, and biotite takes the place of phlogopite in some specimens. Zircon is a minor constituent, and pyrite is occasionally present. According to Gellatly, the proportion of major constituents in the thin sec-

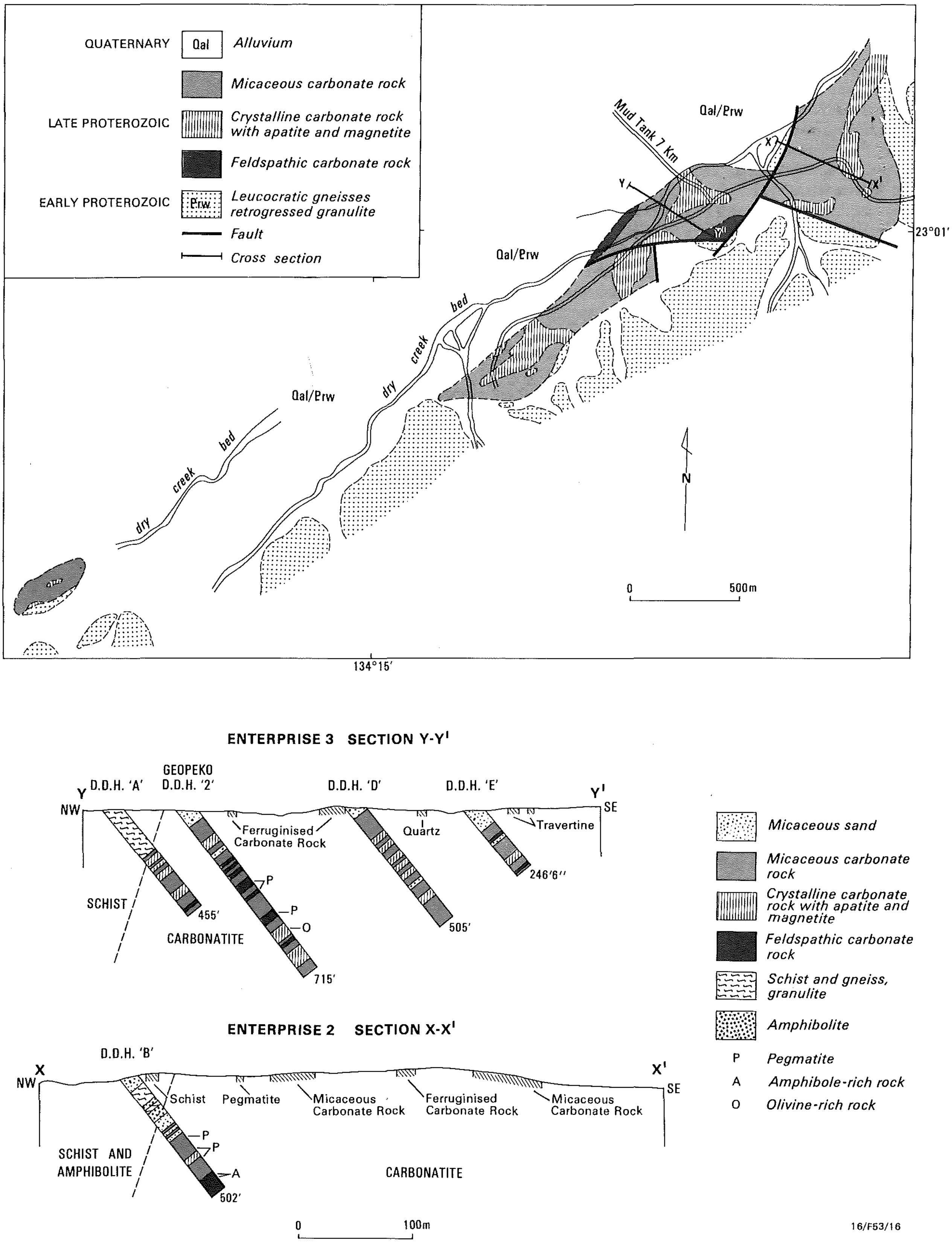

Figure 2. Geology of the Mud Tank Carbonatite (after Moore, in prep.).
Drill-hole cross-sections, after Crohn, 1971.

tions examined by him included calcite 5–90%, dolomite 5–65%, biotite 0–50%, apatite 1–65%, magnetite and ilmenite trace –2%, and the rock types included dolomitic sövite, dolomitic magnetite sövite, biotite sövite, calcitic beforsite and calcite-apatite beforsite. Gellatly and Black & Gulson (1978) recorded reverse pleochroism in the phlogopite, but this was not seen by Moore & Grey (1973) or by us.

The most abundant group of rocks, however, consists of foliated micaceous carbonate rocks, in which pale brown phlogopite, in places somewhat chloritised, is a major constituent, and is responsible for the strongly foliated appearance of these rocks. Subordinate soda-amphibole and minor apatite and magnetite are again typically present. These rocks are under-represented in outcrop, because they are not particularly resistant to erosion, but they make up just on two-thirds of all core recovered from diamond-drill holes in the carbonatite, and, by extrapolation from recent auger drilling results, they are believed to underlie most of the non-outcropping portions of the complex.

A third group of rocks contains feldspar (typically sodic plagioclase) as well as carbonates, and possibly represents a series intermediate between carbonatites and 'normal' igneous rocks. The feldspar in one specimen from Geopeko DDH Enterprise 2 was identified by Gellatly (1969) as andesine (Ab_{34}); other specimens show sericitised cores indicative of zoning (Crohn, 1971). The rocks also contain various amounts of green-brown amphibole, brown biotite, and subordinate clinopyroxene. Apatite, iron oxides and pyrite may again be present in minor amounts. Although widely distributed, this is a relatively minor phase and individual occurrences appear to be generally small. They bear some resemblance to fenites as recorded from other carbonatite complexes, but differ in occurring within the carbonatite complex rather than in the contact zone of the country rock (Fig. 2), and also in their contents of calcite and/or dolomite, which are not found in typical fenites (Le Bas, 1981).

There are also minor occurrences of rocks composed almost entirely of amphibole and biotite in various proportions, and often in close association with the feldspathic carbonate rocks, and one Geopeko drill hole intersected a 30-cm band composed almost entirely of large serpentinised olivine crystals.

Pegmatites are another minor but fairly widely distributed phase, and typically consist of sodic plagioclase, subordinate carbonates, biotite, minor soda-amphibole and/or aegirine-augite, and accessory apatite.

Where some of these different rock types are seen in juxtaposition in diamond-drill cores, contacts are generally gradational over distances of a few centimetres or tens of centimetres. An exception is provided by the feldspathic carbonate rocks, which in places show sharp contacts against the crystalline carbonate rocks, but their age relationships have not been established. The pegmatites also generally show sharp contacts against all other rock types and probably represent a late phase. Gellatly (1969) suggested that these may represent rheomorphic fenites. However, in that case, it is difficult to see why they should apparently occur only within the carbonatite complex rather than in the country rock, and they would be expected to form one of the earliest, rather than one of the last, phases of the complex. The olivine-rich band, on the other hand, is associated with a zone of strongly sheared carbonate rocks and may represent a narrow infaulted wedge or an inclusion carried up during the emplacement of the complex from an originally remote, possibly much deeper location.

From their wide distribution, crystalline texture, and relatively simple mineralogy, it is considered that both the crystalline carbonate rocks and the foliated micaceous carbonate rocks are the products of crystallisation from a carbonatite magma. The foliated micaceous carbonate rocks show considerable variation, particularly in mica content, and their crystallisation may have occurred concurrently with some movement and segregation of constituents during the last stages of consolidation.

The feldspathic carbonate rocks and the amphibole-rich rocks, on the other hand, appear to represent the products of crystallisation from a magma that was undergoing considerable modification, either by differentiation or by assimilation of pre-existing rocks, either country rocks or earlier phases of the carbonatite. In particular, a characteristic even-grained granular or slightly porphyroblastic texture of some of the feldspathic carbonate rocks is suggestive of a hybrid origin. They may represent xenoliths of gneisses or granulites in an advanced stage of assimilation, and some of the amphibole-rich rocks may similarly represent remnants of amphibolite xenoliths. Their origin, as previously indicated, has some of the characteristics of fenitisation, although their spatial distribution and mineralogy differ from those of typical fenites. The results of age determination studies also support the view that these rocks are not part of the main sequence of crystalline carbonate rocks and foliated micaceous carbonate rocks.

Geochemistry

Trace element determinations have been carried out on 13 samples of diamond-drill core from the deepest Geopeko drill hole (Crohn & Gellatly, 1968; Gellatly, 1969), and on 88 scrape samples at 6-m intervals from all Mines and Water Resources Branch cores (Crohn, 1971) (Table 1).

The highest value for niobium was obtained from a specimen containing suspected pseudomorphs after pyrochlore. Copper, zinc, cobalt, nickel, vanadium, chromium, and titanium are higher than average in magnetite-bearing and pyrite-bearing specimens, while at least some of the high values for rare earths (La, Pr, Nd and Y) tend to be associated with apatite-rich samples. Most elements did not show any regular distribution patterns, but barium and strontium tended to show generally higher values in the lower portion of DDH E, i.e. towards the base of the complex.

In general, the trace element concentrations fall within the range exhibited by carbonatites. Gellatly (1969) made a number of specific comparisons, in which he found, among others: Niobium comparable to values recorded from Spitzkop (South Africa), Darkainle (Somali Republic), and Sangu (Tanzania); barium and strontium comparable to Tundulu (Malawi), Dorowa (Zimbabwe), and Shawa (Zimbabwe); lanthanum and yttrium comparable to Mbeya (Tanzania) and Darkainle; and neodymium and praseodymium comparable to Sangu.

Table 1. Trace element values, Mud Tank Carbonatite

Nb	< 20–450 ppm	Cu	10–300ppm
Ba	175–3000	Zn	< 100–100
Sr	40–1500	Pb	2–6
La	< 100–1000	Co	8–125
	(one sample > 1000)	Ni	10–530
Pr	< 100–100	V	10–900
Nd	< 300–300		(one sample > 1000)
Y	16–200	Cr	10–60
Rb	< 3–500		

Ba, La, Cu, Co, Ni — direct reading optical spectrography.
Other elements — optical emission spectrography.

Isotopic and age determination studies

A study of strontium isotopes by Moore & Grey (1973) generally supported a carbonatite origin for the Mud Tank Carbonatite, as did studies of oxygen and carbon isotopes by Wilson (1979).

Age determinations by Black & Gulson (1978) indicated ages of 732 ± 5 Ma from U-Pb in zircon, and 735 ± 75 Ma from whole rock Rb-Sr analyses of the carbonate rocks. These do not coincide with any other known igneous or metamorphic event in this general area, and are substantially younger than the surrounding Early Proterozoic rocks.

Results from two feldspathic carbonate rocks and one amphibole-rich rock did not fall on the isochron for the remaining samples, supporting the suggestion that they are contaminated or temporally distinct phases. Determinations based on Rb-Sr in three biotite samples gave ages of 319, 349, and 329 Ma, indicating that these have been affected by younger earth movements or metamorphism, possibly related to the Alice Springs Orogeny.

Economic potential

Interest was originally directed to this occurrence as a possible source of phosphate (Owen, 1944; Williams, 1967), but, on the available evidence, the apatite content of the unaltered rocks is too low for development, and the near-surface enriched material, probably resulting from selective leaching of the carbonate fraction of the rocks, is insufficient to support a mining operation. Rare-earth, niobium, and base-metal concentrations also appear to be below economic levels.

With regard to zircon, most of the larger crystals are flawed and discoloured, but smaller specimens of gem-quality material are not uncommon, and the area now regularly attracts fossickers searching for this type of material in the soil and colluvium overlying the carbonatite.

The mica of the carbonatite within the weathered zone (generally within about 40 m of the surface) and in the overlying soil and colluvium, shows bloating properties, i.e. it expands on heating to several times its original volume, and may therefore have commercial value for thermal insulation or as a soil conditioner or light-weight aggregate. The bloating material was originally called vermiculite (Crohn, 1971), but has recently been identified by X-ray crystallography as a member of the hydrobiotite/hydrophlogopite series (Moore, in prep.). Current investigations by the Northern Territory Department of Mines and Energy are largely designed to test the possibility of economically developing this material.

Comparison with other carbonatites

Most recorded carbonatites, including such well-documented occurrences as Palabora (South Africa), Oka (Canada) and Alnö (Sweden) occur in ring structures, are closely associated with alkaline intrusive rocks, and have given rise to extensive fenitisation (alkali metasomatism) of their host rocks. They generally also occur close to major structural lineaments and show distinctive trace element values and stable isotope ratios (Le Bas, 1981). The Mud Tank Carbonatite conforms in occurring close to a major lineament (the Woolonga Lineament) and in its geochemical and isotopic characteristics, but lacks the ring structure, the associated alkalic rocks (except for very minor pegmatites), and the fenitisation (except for the development of soda-amphibole in the host gneisses within about 50 cm of the carbonatite contact).

A limited number of carbonatites comparable to the Mud Tank Carbonatite in shape and in the absence of associated alkalic rocks have, however, been recorded. They include Sangu and Songwe Scarp in Tanzania (Tuttle & Gittins, 1966), Newania in India (Viladkar, 1980) and an occurrence in the Ukrainian Shield (Kapustin & others, 1978). These may represent deeper levels of erosion than the typical ring complexes. In addition, the Indian and Ukrainian examples are associated with sodic rather than potassic fenitisation, which Le Bas (1981) also considered to be characteristic of deeper levels of erosion. Comparable sodic fenitisation is not typical of ring complexes. However, one recorded example from Sokli in Finland is of interest in that this complex is thought to consist of a core of magmatic carbonatite surrounded by a zone of meta-carbonatite — carbonate and carbonate-silicate rocks resulting from the replacement of pre-existing, possibly mafic rocks by CO_2-rich fluids from the carbonatite magma (Vartianen & Paarma, 1979).

The Mud Tank Carbonatite, has only given rise to very minor fenitisation of the surrounding gneisses, but the mineralogy of the feldspathic carbonate rocks, the amphibolite-rich rocks, and the pegmatites is, in each case, indicative of enrichment in sodium rather than potassium. Moreover, the suggested hybrid origin of the feldspathic carbonate rocks and the amphibole-rich rocks appears to bear some resemblance to that of the Sokli metacarbonatites, and the pegmatites may be the products of crystallisation from an alkali-rich residual fluid containing those components that in other carbonatite complexes have penetrated the host rocks to give rise to typical fenitic aureoles.

Acknowledgement

References to unpublished reports of the Northern Territory Department of Mines and Energy are included by permission of the Secretary of that Department, which is gratefully acknowledged.

References

Anfiloff, W. & Shaw, R.D., 1973 - The gravity effects of three large uplifted granulite blocks in separate Australian shield areas. *In* Mather, R.S., & Angus-Leppan, P.V. (editors), *Proceedings: Symposium on Earth's gravitational field and secular variations in position. Sydney, 1973.* 273-278.

Black, L.P., & Gulson, B.L., 1978 - The age of the Mud Tank Carbonatite, Strangways Range, Northern Territory. *BMR Journal of Australian Geology & Geophysics,* 3, 227--232.

Crohn, P.W., & Gellatly, D., 1969 - Probable carbonatites in the Strangways Range area, Central Australia. *Australian Journal of Science, 31, 335-336.*

Crohn, P.W., 1971 - Investigations at the Strangways Range carbonatite locality, Northern Territory, 1969-1970. *Mines Branch, Northern Territory Administration; Records Northern Territory Geological Survey* 1971/1 (unpublished).

Flavelle, A.J., 1965 - Helicopter gravity survey by contract - Northern Territory and Queensland, 1965. *Bureau of Mineral Resources, Australia, Record* 1965/212.

Gellatly, D.C., 1969 - Probable carbonatites in the Strangways Range area, Alice Springs 1:250 000 Sheet area SF 53/14: petrography and geochemistry. *Bureau of Mineral Resources, Australia, Record* 1969/77.

Jensen, H.I., 1943 - Notes on the phlogopite mine, Strangways Range area. *Bureau of Mineral Resources, Australia, Unpublished Report, Resident Geologist's Office, Alice Springs.*

Kapustin, Y.L., Lapitski, E.M., Pogrebnoy, V.T., Storchak, P.N., & Kochanov, Y.N., 1978 - The carbonatite zone of the Ukrainian Shield. *International Geology Review, 20, 1131-1140.*

Langworthy, A.P., & Black, L.P., 1978 - The potassic Mordor Complex, central Australia. *Contributions to Mineralogy and Petrology,* 67, 51-62.

Le Bas, M.J., 1981 - Carbonatite magmas. *Mineralogical Magazine,* 44, 133-140.

Moore, A.C., 1973 - Carbonatites and kimberlites in Australia: a review of the evidence. *Minerals Science and Engineering,* 5(2), 81-91.

Moore, A.C., & Grey, C.M., 1973 - Carbonatites of the Strangways Range, central Australia: evidence from isotopes. *Journal of the Geological Society of Australia,* 20(1), 71-73.

Moore, D.H., in prep. - The Mud Tank vermiculite prospect, Alice Springs 1:250 000 Sheet area SF 53/14. *Northern Territory Government, Department of Mines and Energy, Northern Territory Geological Survey Records* (unpubl.).

Owen, H.B., 1944 - Report on an occurrence of apatite on Alcoota Station, Alice Springs District, Northern Territory. *Bureau of Mineral Resources, Australia, Record* 1944/44.

Stillwell, F.A. 1943 - Rock specimens from Strangways Range, Northern Territory. *Mineragraphic Investigations of the Council for Scientific and Industrial Research, Report No.* 288.

Tipper, D.B., 1966 - Strangways Range aeromagnetic survey, Northern Territory, 1965. *Bureau of Mineral Resources, Australia, Report* 136.

Tuttle, D.F. & Gittins, J. (editors) 1966 - Carbonatites. *J. Wiley, London.*

Vartianeń, H., & Paarma, H., 1979 - Geological characteristics of the Sokli Carbonatite Complex, Finland. *Economic Geology,* 74, 1296-1306.

Viladkar, S.G., 1980 - The fenitised aureole of the Newania carbonatite, Rajasthan. *Geological Magazine,* 117, 285-292.

Williams, B.T., 1967 - Report on the investigation of the Enterprise 2 group of prospects, Strangways Range, Northern Territory. *Geopeko Ltd, unpublished report.*

Wilson, A.F., 1979 - Contrast in isotopic composition of oxygen and carbon between the Mud Tank Carbonatite and the marble in the granulite terrane of the Strangways Range, Central Australia. *Journal of the Geological Society of Australia,* 26(1-2), 39-44.