Rare earths and vanadium in the northern Barkly

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Transition Minerals Limited has reported an initial rare earth element (REE) Inferred Mineral Resource of 40 Mt at 2100 ppm total rare earth oxides (TREO) for its 100%-owned Barkly Project in the Northern Territory. In addition, a combined initial vanadium Inferred Mineral Resource of 200 Mt at 0.12% V_2O_5 and 30 ppm Ga has also been reported in accordance with the JORC Code (2012). Exploration Targets for REE and vanadium have also been assessed, demonstrating significant upside potential for both REE and vanadium mineralisation.

Mid-Cretaceous flooding of the northern Australian margin appears to have occurred during two main intervals – first in the late Aptian and second from the middle Albian through to the early Cenomanian. The transgressive peak of the epeiric seaway was reached at the Albian–Cenomanian boundary. The Jurassic–Cretaceous intracratonic Carpentaria Basin is one of a series of time-stratigraphic equivalent, partially to fully overlapping, nested basins (including the Eromanga, Surat, Warburton and Laura basins) that forms the northern part of the Great Australian Superbasin. The Jurassic sediments lie to the east of the depocentre, and the Cretaceous sediments gradually onlap and attenuate (through surfaces or omission) to the west of the basin in the Barkly region. Here they have been informally classified as the Mullaman beds (initially, the Inland Suite of Skwarko 1966) and more recently as the Walker River (Aptian-age) and Yirrkala (Albian-age) formations (Krassay 1994). In the project area, their distinction is not clear (the ubiquitous basin-wide chronostratigraphic C2 marker separating the formations has not yet been identified), so the informal term of Mullaman beds is used.

Basin geometry has played a distinct role in the sedimentary environment and stratigraphic packaging of the REE- and vanadium-bearing sediments at Barkly. The deposits reside within shallow marine sediments deposited in an elongate east–west-trending marine palaeoembayment with dimensions of ~200 km × 90 km. As a result, the heterogeneity of the sediment facies, their stratal architecture and thickness, and possibly their mineral speciation, is expected to vary due to their different geographic localities and the interplay between terrestrial and marine influences within such a large, sheltered embayment. This environment effectively forms its own sub-basin. Regionally, these relatively low-energy, siliciclastic sediments accumulated on a gently sloping epeiric shelf, which formed the western margin of the Carpentaria Basin. Due to their locality, it is thought that the sediments within the palaeoembayment have their thickest accumulation in quiet-water in sheltered near-shore zones where deposition was largely restricted.

In terms of sequence stratigraphy, Lowstand Systems Tracts are poorly developed in the project area, with stacked Highstand and Transgressive System Tracts reflecting deposition on a broad, low-gradient shelf, where small changes in relative sea level resulted in major changes in depositional architecture. Previous investigations suggest that the broad shallow shelf maintained a relatively similar configuration throughout the mid-Cretaceous with water depths rarely exceeding 50 m depth and apparently within the influence of storm waves over much of the area. The shelf appears to deepen eastward toward the open Carpentaria seaway and the basin depocenter situated in Queensland. In summary, the preserved sediments form generally coarsening- and shallowing-upwards facies successions, which were aggradational during high relative sea level and progradational in nature during falling relative sea level. Some of these successions were subsequently eroded during further cyclic fluctuations of relative sea level.

REE mineralisation

It is thought that early diagenetic phosphatic minerals containing REE and vanadium precipitated within oxygen-poor bottom-water conditions that led to the formation of pyritic fine-grained rocks being deposited under dysaerobic to anaerobic conditions (redox cycling under burial diagenesis). This occurred in zones of sulfate-reduction and methanogenesis from the decomposition of biogenic/organic material coating on detrital particles, which allowed the release of adsorbed oceanic REE. The organic debris is thought to be provided by fossilized fish bones from the open ocean and by pelagic mud sources provided from upwelling on the shelf break, as well as by contributions of river-borne organic material from terrestrial sources under terrestrial (estuarine) conditions.

The mixing of saline and fresh water is thought to have provided the necessary conditions for the coagulation of the organic colloids and their precipitation. REE-enriched sediment pore waters in organic-rich sediments then precipitated the REE minerals during burial diagenesis. Mineral characterisation studies have determined that the REE-bearing minerals are of the aluminium–phosphate–sulfate (APS) suite and comprise a solid-solution series of the principal minerals gorceixtite (Ba), goyazite (Sr) and florencite (REE).

The REE-bearing unit is thought to be a bottom-loaded sediment where biogenic material easily accumulated on the sea floor prior to burial. The role of pedogenesis following subaerial exposure is unknown, but the Cretaceous sea receded permanently in the Late-Albian so the shallow shelf sediments may have been exposed for a lengthy period. In addition, percolating meteoric and mixed saline brines may have contributed to REE enrichment by supergene processes.

Vanadium mineralisation

It seems likely that the vanadiferous unit (the Vanadis Unit), superposed a few metres stratigraphically from the REE-bearing zone, may have been deposited in the same manner

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as the REE mineralisation. However, it is suggested by some that the vanadium was liberated from pyritic muds, ie oxygen-poor bottom water conditions, which is also appropriate for the shallow, slack-water environment that is postulated for much of the protected marine embayment.

The vanadium may occur as a variety of both organic and inorganic species (as with the Toolebuc Formation; Riley and Saxby 1986), suggesting a combination of similar physical and chemical anoxic and sulfidic conditions, including inorganic colloidal material in solution (per REE deposition), may have been involved in the accumulation of the extensive resources that have been outlined and inferred.

The vanadium source has also been considered by some to be derived from weathering and erosion of the hinterland adjacent to the Eromanga Basin. In the Barkly area, remnants of dykes, sills and intrusions of the Kalkarindji Event large igneous province (LIP) have been mapped. These inliers show the distribution of the LIP to be wide-ranging, extending as far as the Antrim Plateau Basalts in the Limbunya area to the west. If sufficient dykes and sills of Kalkarindji Event mafic rocks were present, they may represent a plausible source of elevated vanadium levels in terrestrial water flowing into the Carpentaria Basin.

References

Krassay AA, 1994. The Cretaceous geology of northeastern Arnhem Land, Northern Territory. Mineral Provinces 39. *Australian Geological Survey Organisation, Record* 1994/40, 1–85.

Riley KW and Saxby JD, 1986. Organic matter and vanadium in the Toolebuc Formation, northern Eromanga Basin and southern Carpentaria Basin. *Geological Society of Australia, Special Publication* 12, 267–272.

Skwarko SK, 1966. Cretaceous stratigraphy and palaeontology of the Northern Territory. *Bureau of Mineral Resources, Australia, Bulletin* 73.