The Woodleigh impact structure

by

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The Woodleigh structure is a newly discovered, buried, multi-ring impact feature, approximately 120 km in diameter on the Gascoyne Platform of the Southern Carnarvon Basin. The centre of the structure lies on Woodleigh Station (after which it is named) approximately 160 km south-southeast of Carnarvon and directly east of Hamelin Pool in Shark Bay (Fig. 1).

The structure was first identified as an impact crater in late 1997 during a geological review of the Gascoyne Platform (Iasky and Mory, 1999). Shallow granitic rocks in the Woodleigh 1981/2 drillhole (Layton and Associates, 1981) coincide with the centre of a circular gravity anomaly. Initial modelling showed that the granite in Woodleigh 1981/2 has lower density than the average crystalline basement, indicating the possibility of an impact structure. In addition, photomicrographs of cuttings samples of the granite in the Woodleigh 1981/2 well completion report showed possible planar deformation features (PDF) typical of shock metamorphism. Unfortunately, all of the original samples had been lost or destroyed, so the Geological Survey deepened the original hole in March 1999 (GSWA Woodleigh 1) to verify the impact interpretation. The granite core shows extremely well preserved shock-metamorphic features including thin veins of melted glass (pseudotachylite), breccia, and PDFs, thereby providing indisputable evidence of an impact origin. Subsequently, a second corehole (GSWA Woodleigh 2A) was drilled 13 km to the west of the first to sample the crater-infill section.

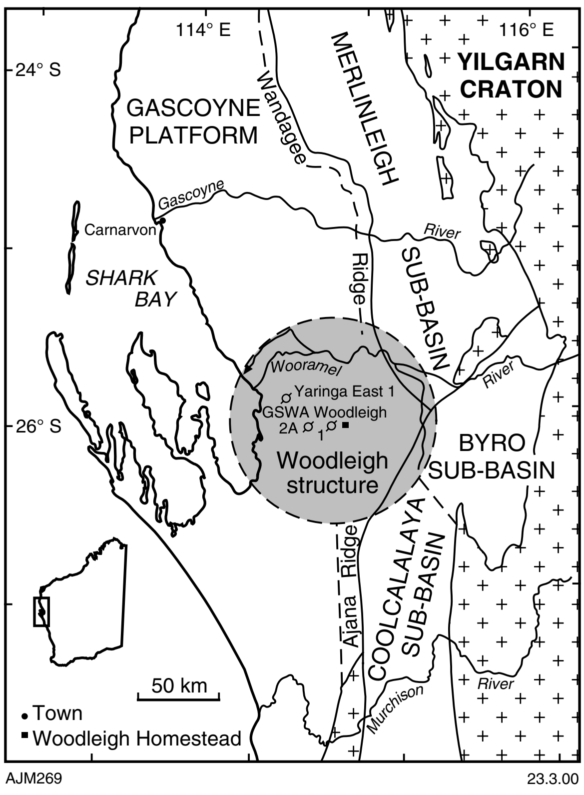

Figure 1. Geographic location and structural sketch map of Woodleigh impact structure, southern Carnarvon Basin, Western Australia

The structure is most clearly shown on the first vertical derivative of the Bouguer gravity as a series of annular ridges and troughs (Fig. 2). The central gravity 'high', approximately 25 km in diameter, is interpreted as the central uplift of the impact. The adjacent gravity 'trough' probably corresponds to a ring syncline filled with the breccia seen in GSWA Woodleigh 2A. Both of the northerly trending Ajana and Wandagee Ridges apparently terminate against the structure 60 km from its centre. In the southeast, the outermost ring is cut by the Madeline Fault, which separates the crater area from the Byro and Coolcalalaya Sub-basins. The outermost ring is not discernable within Shark Bay, where there are no gravity data.

Core from GSWA Woodleigh 1 indicates that the impact shock reduced the density of the basement. The lower density granite was modelled to a depth of about 2.5 km, and a width of about 3.5 km (Fig. 3). The adjacent lower density layer, however, can be interpreted as either highly brecciated low-density basement (making the central uplift area about 20 km across), or as low-density sedimentary rock. The gravity model shows broad folds that decrease in amplitude with increasing distance from the centre. East of the Madeline Fault, the structural style consists of tilted fault-blocks, quite distinct from the style

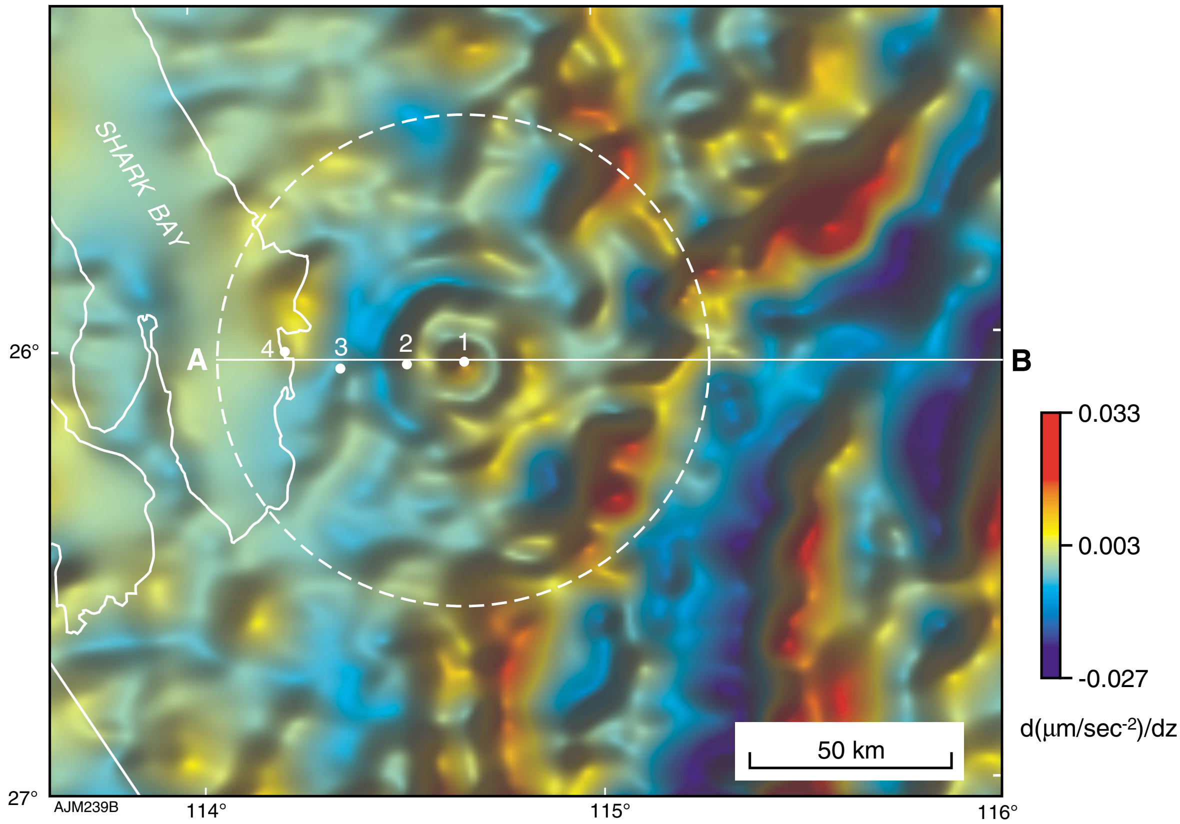

Figure 2. First vertical derivative of Bouguer gravity image of the Woodleigh structure. Illuminated from southeast. 1 = GSWA Woodleigh 1, 2 = GSWA Woodleigh 2A, 3 = Yaringa 1, 4 = Hamelin Pool 1

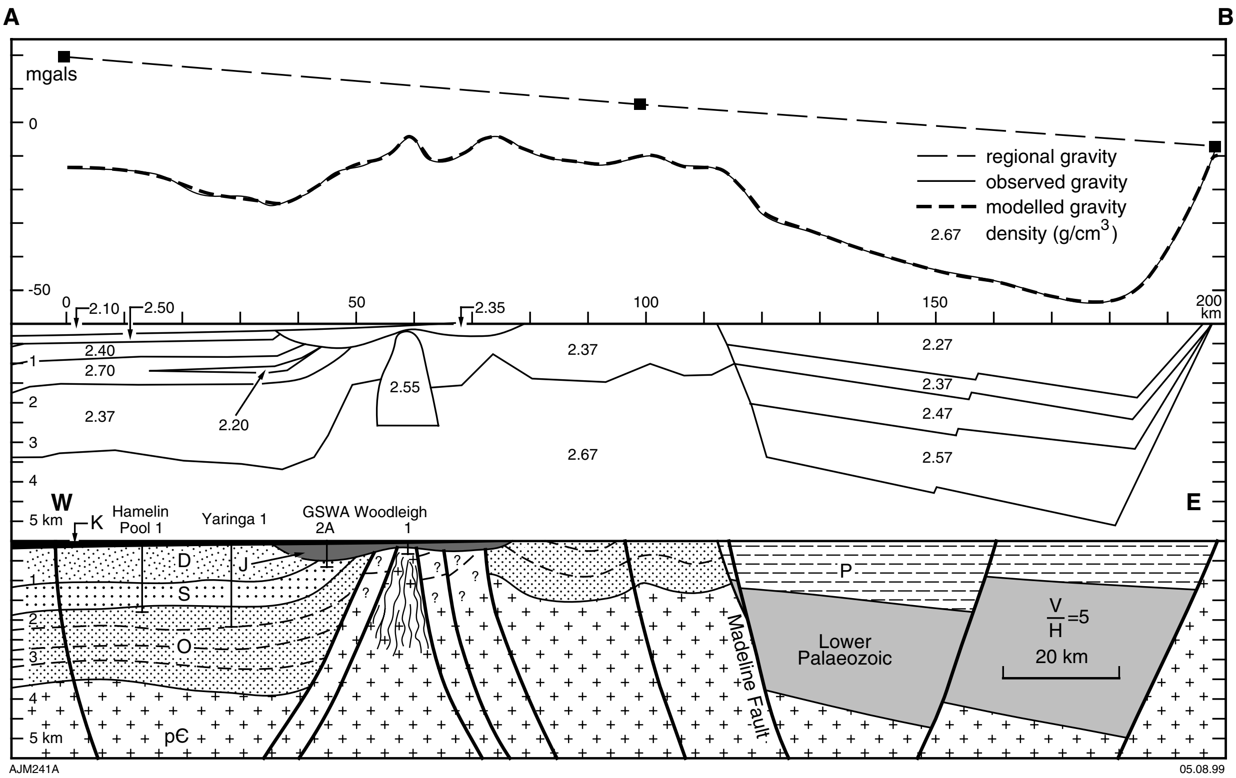

Figure 3. East–west gravity model and cross section through the Woodleigh structure. Section A–B in Figure 2. The thin Cretaceous cover is not represented in the cross section. Densities used in the model are from core and well logs in the region. K = Cretaceous, J = Jurassic, P = Permian, D = Devonian, S = Silurian, pЄ = Precambrian, ? = Silurian or low-density brecciated Precambrian. Line of section shown on Figure 1

of deformation to the west. An east–west seismic section supports the gravity model by showing a change in structural style across the Madeline Fault. To the west of the fault, chaotic reflections are due to extensive brecciation and faulting associated with the impact. At about 25 km west of the centre of the structure, however, there are curved reflections that correspond to a gravity ridge (Fig. 2). The gravity and seismic data indicate that the Woodleigh structure is asymmetric in the east–west direction, with basement east of the central peak being about 2 km shallower than to the west. The asymmetry is interpreted as tilting during the Early Cretaceous deformation of the Gascoyne Platform (Iasky and Mory, 1999).

In contrast with other impact structures such as Chicxulub, Gulf of Mexico (Sharpton et al., 1996), the only significant magnetic anomaly detected from the BMR aeromagnetic survey (1956–1961 vintage) is an arcuate anomaly along the eastern outer margin of the structure. This anomaly is coincident with the outermost gravity ring about 60 km from the centre of the structure. Modelling of the arcuate anomaly indicates that it originates from a depth of about 5 km. The anomaly closely coincides with a drainage divide and overlapping creek system implying re-activation of the boundary ring fault, possibly during the Miocene compressive event documented elsewhere in the region (Iasky and Mory, 1999).

A comparison of ground magnetic with the BMR aeromagnetic data along an east–west traverse between GSWA Woodleigh 1 and 2A shows that a ground magnetic anomaly in the centre of the structure was only partially detected by the BMR aeromagnetic survey. The BMR survey was flown at 150 m with traverses spaced at 1600 m, and much of the signal is lost or smoothed by the gridding process. A modern high-resolution aeromagnetic survey should resolve the magnetic anomaly in the centre, and also along the edge, of the structure.

Initial studies constrain the age of the Woodleigh impact to between Early Permian and Early Jurassic (290–200 Ma). The Lower Jurassic lacustrine crater-infill (Woodleigh Formation) defines the younger age limit of the impact. At present the older age limit is constrained by shale clasts containing Early Permian palynomorphs from the basal 8 m of the Woodleigh Formation in GSWA Woodleigh 2A. On presently available data the re-worked Lower Permian clasts were sourced from the Byro or Coolcalalaya Sub-basins, over 55 km from the centre of the structure. However, the presence of Lower Permian strata within the upper part of the structure that was eroded in pre-Jurassic times cannot be excluded. Isotope dating of the shock-metamorphosed gneiss recovered by GSWA Woodleigh 1, has yet to conclusively determine the age of impact. Although a regional thermal event identified by apatite fission track at 280–250 Ma hints at an age close to the Permian–Triassic boundary, the lack of Triassic fossils in the crater fill favours a younger age.

With an estimated diameter of 120 km, the Woodleigh impact structure is the largest found in Australia and the fourth largest in the world after Vradefort, South Africa (300 km), Sudbury, Canada (250 km), and Chicxulub (170 km). To date, a total of 160 terrestrial impact structures have been recognized, of which 26 are in Australia. The size of the Woodleigh impact structure suggests that it may have had a significant role in the tectonic evolution of the Southern Carnarvon Basin — if the hypothesis that large impacts may trigger tectonism (Hughs et al., 1977; Jones, 1987) is accepted. Apart from such tectonic implications, an impact of this size would have caused catastrophic environmental effects that, on the present dating of Woodleigh, may correlate with the end of Triassic or end of Permian mass extinctions.

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Regolith geochemistry in sand-dominated terrain: a case study of the Ajana 1:250 000 sheet

by

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The Geological Survey of Western Australia (GSWA) regolith geochemical mapping program provides information on the distribution and composition of regolith to assist bedrock mapping, and to stimulate mineral exploration. This program, which has largely focused on the Yilgarn Craton and adjacent Proterozoic basins, has established a simple relationship between bedrock composition and regolith geochemistry. Recently, the program has included Phanerozoic basins, where limited outcrop and extensive sand and vegetation cover create new challenges in interpreting regolith geochemistry. Despite this, some encouraging results were obtained that are applicable to sampling in sand-dominated terrains elsewhere in Western Australia.

The AJANA 1:250 000 sheet (Fig. 1) includes parts of the Archaean Yilgarn Craton, Proterozoic rocks of Badgeradda Group, Nilling Formation and Northampton Complex, and Phanerozoic rocks of the Coolcalalaya Sub-basin and Southern Carnarvon Basin (Myers and Hocking, 1998). Regolith and regolith geochemical mapping of AJANA was based on regolith characteristics and sampling of regolith at 820 sites at a nominal density of one sample per 16 km^2. The <2mm fraction of the sample was subsequently analysed for 48 elements by a commercial laboratory.

A regolith-materials map was produced using Landsat imagery, aerial photography, synthetic Landsat stereopairs, and sample-site descriptions. Sand-dominated regolith, which accounts for 65% of all regolith on AJANA, was divided into eleven types, based on lithology and geomorphology. Vegetation patterns, in conjunction with periodic fire scarring (resulting in soil destabilization) and recent faulting may have influenced the morphology of some of these sandplain units. In some coastal areas, the sandplain types reflect coastal processes, with significant dune development. Many sandplain subdivisions can be distinguished by subtle chemical variations, suggesting that sandplain chemistry is controlled by several factors, including sand stability, coastal and eolian processes, and the nature of the underlying lithology (Sanders and McGuinness, in press). A simplified version of the regolith-materials map is produced in Figure 2.

Owing to the predominance of quartz sand, many analytes are diluted by SiO_2 and variations in the chemistry of the sandplain are subtle. In the northwest of AJANA, P_2O_5 values in regolith are higher over areas of relatively stable undulating sandplain, whereas lower values are encountered over adjoining depressions and drainage areas, typically dominated by net-like dune systems. The higher P_2O_5 values in the more stable sandplain probably relate to the presence and reworking of underlying carbonates. This area also contains some of the highest Zr values in regolith for the map sheet. As samples containing high Zr are found in zones parallel to the coast, are continuous across numerous regolith types, and are progressively depleted in an easterly direction, it is proposed that the high Zr values represent concentrations of heavy mineral sands enriched by coastal processes (Sanders and McGuinness, in press).

To test the hypothesis that many of the sandplain units on AJANA are chemically different, k-means cluster analysis was undertaken to divide the samples into several chemically distinct groups (Rock, 1988). This approach shows that most of the map sheet is covered with quartz-rich sandplain, although along the coast, the higher SiO_2 concentrations have given way to more carbonate-rich material (Fig. 1). Some of these coastal areas include the highest levels of resistate phases in regolith, including such detrital minerals as rutile, ilmenite, monazite, sphene and zircon. Heavy mineral concentrates constitute up to 4% in some samples. These have probably been derived from the Northampton Complex and Yilgarn Craton and transported by the Murchison River and concentrated by eolian processes, along palaeoshorelines, or in the mouth of a proto-Murchison River (Sanders and McGuinness, in press; Harrison, 1985).

There may be evidence of base metal mineralization in the sand-dominated environment but this requires more detailed work involving low-level detection of pathfinder elements.

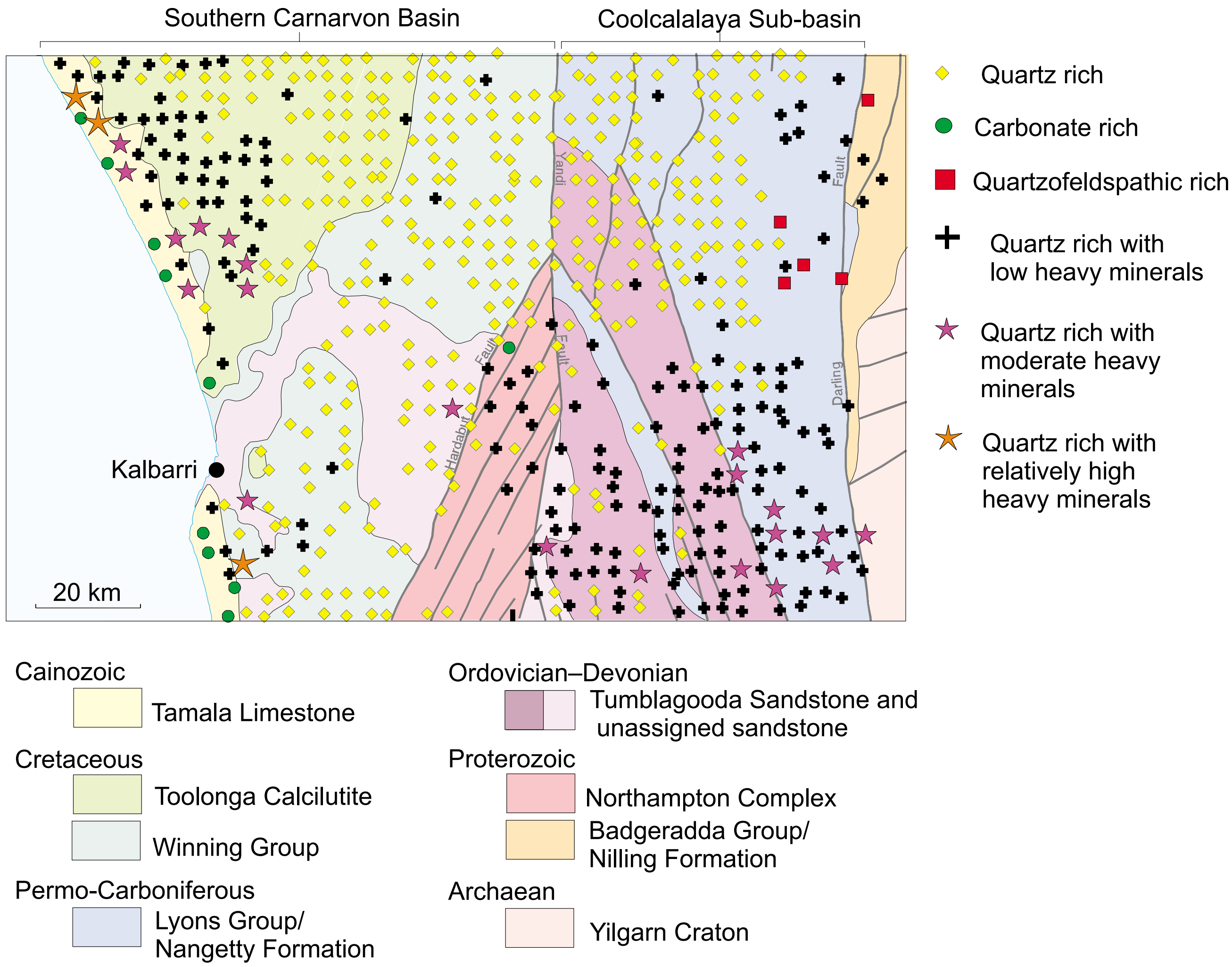

Figure 1. Simplified geology and classification of sand composition after k-means cluster analysis

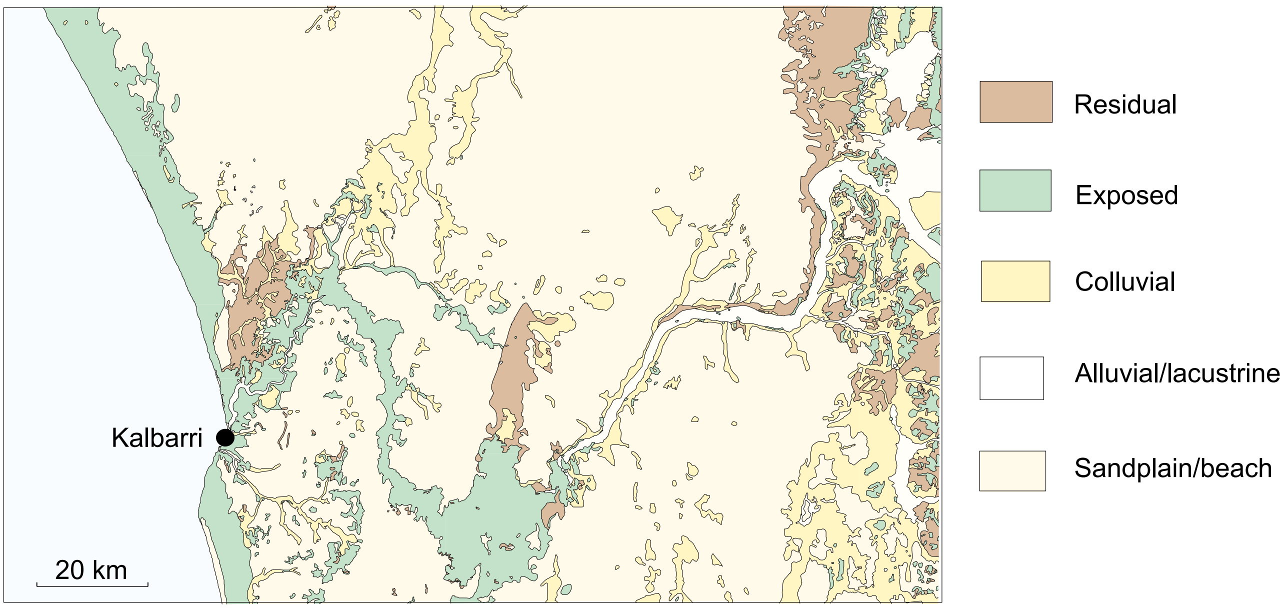

Figure 2. Simplified regolith highlighting the dominance of sandplain on AJANA

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