Australian Government
Geoscience Australia

AUSGEO news
ISSUE 109 Mar 2013

Groundwater Investigations in palaeovalleys in the Murchison region

Finding hidden water resources for remote townships and expanding mining activities

Pauline English

Australia's arid zone and water supplies

Secure, reliable and accessible water supplies are essential across the whole of Australia. The extensive arid parts of the country are dependent upon groundwater to meet the often competing requirements of remote towns, isolated Aboriginal communities, the pastoral and mining industries and the environment. Greater understanding and predictability of groundwater resources in these regions is imperative for current and sustainable future water supplies.

Palaeovalleys—sediment-filled old river valleys that exist across much of the continent and which are commonly obscured beneath dunefields and other cover materials—offer a hidden groundwater resource across much of arid Australia. They are particularly important in cratonic provinces where no other significant aquifers exist. The potential of palaeovalley aquifers is beginning to be 'uncovered' to increase understanding of these distinctive aquifers towards long-term sustainability of their precious groundwater resources.

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Geoscience Australia has completed a regional-scale project on: 'Water for Australia's arid zone—Identifying and assessing Australia's palaeovalley groundwater resources' (English et al, 2012), funded by the National Water Commission (NWC) and supported by respective state government agencies. The work investigated palaeovalleys across arid and semi-arid parts of Western Australia, South Australia and the Northern Territory, including 'demonstration studies' involving fieldwork in widespread regions in different geologic provinces and climatic regimes (figure 1). Investigations were directed towards: (a) characterising representative, distinctive and/or broad-scale palaeovalley systems, (b) assessing methodologies that effectively detect and enable mapping of these aquifer systems at regional to local scales, and (c) supporting groundwater resource investigations needed in the immediate or near future, for example, for mining operations and community water supplies. An improved understanding of the Murchison palaeovalleys was designated a strategic priority by the WA Department of Water, particularly for provision of water resources for expanding iron-ore and gold mining operations, and this region was accordingly nominated as a demonstration study for the NWC project.

Murchison Palaeovalleys demonstration project

The Murchison Province is part of the Yilgarn Craton, composed of Archean granite-greenstone terrain, where there is little or no perennial surface water. There are two salt lakes in the study area: Lake Austin, near Cue township, and Lake Annean, near Meekatharra, with the Great Northern Highway situated close to both (figure 2). The whole Murchison district depends on palaeovalley aquifers for water supplies to towns, pastoralists and mining operations. Most of the numerous existing bores are shallow, less than 20 metres deep, and are typically windmill equipped, accessing water from calcrete or near-surface alluvial aquifers. Scant information has previously been available about the full depths of the Murchison palaeovalleys and the nature of their sedimentary infill and groundwater resources. In contrast, palaeovalleys elsewhere in the Yilgarn have been subject to detailed hydrogeologic investigations.

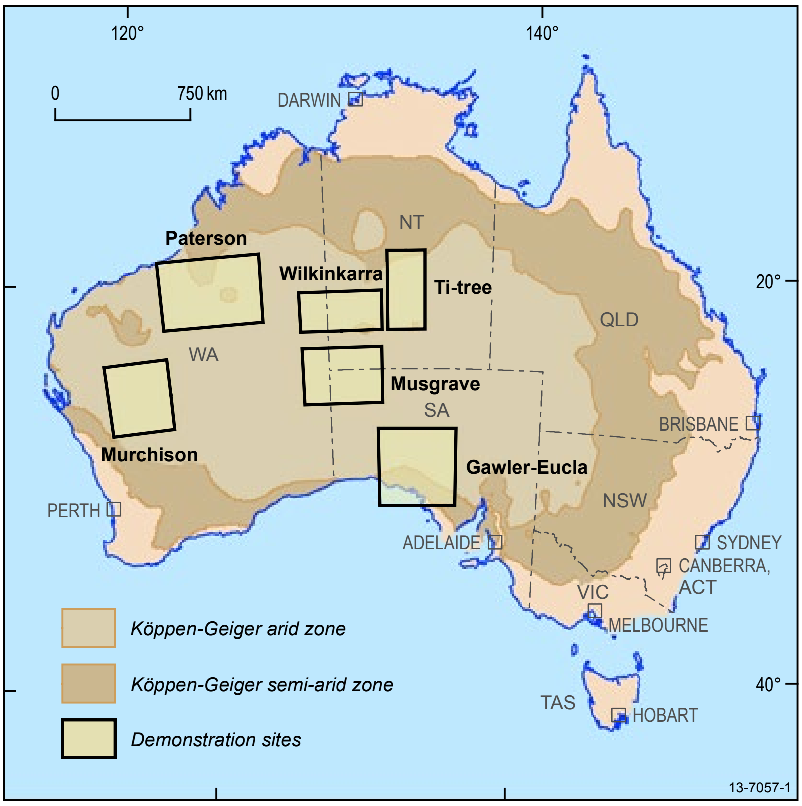

Figure 1. Map of arid and semi-arid zones of Australia, based on the Köppen Geiger climate classification scheme.

Four sites in the Murchison Province (figure 2) were selected for reconnaissance investigation: Beringarra and Mt Padbury stations on the Murchison Palaeovalley (Glenburgh and Byro, and Robinson Ranges 1:250 000 map sheets, respectively), Annean station on the Hope Palaeovalley (Belele 1:250 000 map), and Austin Downs station on the Sanford Palaeovalley (Cue 1:250 000 map). Four methods were used to characterise the palaeovalleys:

- analysis of digital elevation models (DEMs) and derived products
- ground gravity traverses
- drilling and installation of monitoring bores
- hydrochemistry

High resolution Shuttle Radar Topography Mission (SRTM) elevation data were processed to partition the landscape into low-flat and high-steep areas to encapsulate valley extents and networks to provide a basis for ground geophysical traversing. To determine the deepest section of each palaeovalley site, 55 kilometres of ground gravity surveying (130 stations spaced at 400 or 500 metre intervals) were completed. Twelve investigative drill holes (totalling 1195 metres) were sunk using mud rotary and reverse circulation techniques (figure 3). Drilling continued to bedrock wherever possible.

Geophysical and drill-hole data were interpreted to represent the cross-sectional disposition and stratigraphy of the selected palaeovalleys and to guide emplacement of bores (figure 4). Monitoring bores were installed in the deepest part of each palaeovalley at the four study sites, that is, into the sandy basal palaeochannel above the bedrock contact. Screened casing in the bores was inserted in favourable deeper aquifers within the palaeovalley infill. Drill cuttings were logged to determine the stratigraphic and lithologic nature of each hole and for palynological dating; groundwater samples were collected for water chemistry analysis, including stable and radiogenic isotopes. Four new monitoring bores were levelled by surveying, and data loggers installed for time-series measurements of standing water levels (SWL) and salinity monitoring into the future.

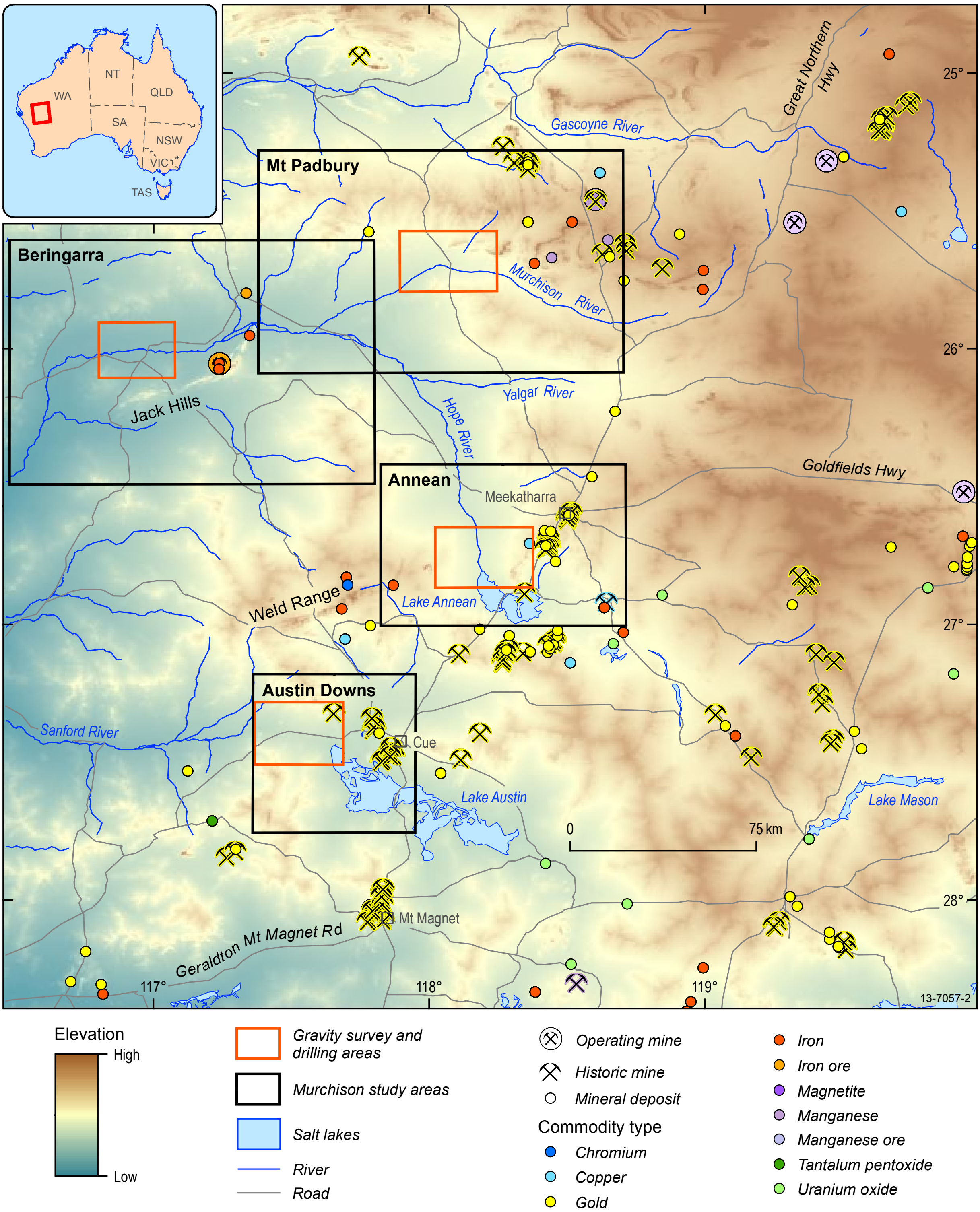

Figure 2. Map of the Murchison region, Western Australia, including study areas for the Palaeovalley Groundwater project and locations of mines, mineral deposits and towns.

Distinctive characteristics of the Murchison palaeovalleys

The Murchison Province palaeovalleys have been incised into Archean bedrock to depths of 150–200 metres below the present ground surface. This contrasts with average depths of around 120 metres in the north-eastern Yilgarn, 60 metres in the south-eastern Yilgarn (Eastern Goldfields), and 40–50 metres in the south-western Yilgarn (Wheatbelt). Geological structures, including faults and major basement contacts (for example, figures 4 and 5), may have influenced incision of the ancient rivers in the Murchison. Buried inset valley profiles are present, indicating multi-phase incision. In places, the palaeo-thalweg and present-day main river channels are offset by up to 2–3 kilometres. This may be attributable to tectonic tilting and/or the role of faulting during the evolution of the palaeovalley systems, or may reflect more recent ephemeral fluvial flow regimes on the flat surface of the now fully infilled valleys. The depositional environment across the region is wholly terrestrial and dominantly fluvial, with subordinate lacustrine or swampy settings. The substantial valley incision, up to 200 metres deep into crystalline bedrock in a valley less than 5 kilometres wide, for example, suggests high-energy fluvial environments.

Figure 3. Reverse Circulation (RC) drilling into buried palaeovalleys that had been defined by gravity profiling.

Sedimentary infill of the Murchison palaeovalleys is sandier than that in other parts of the Yilgarn. This has significant implications for groundwater storage, and for understanding the evolution of the Yilgarn landscape. Sediments in the infilled Murchison palaeovalleys commonly consist of coarse, immature sands that are indicative of local provenance, and which may form alluvial aquifers with high porosity and transmissivity properties. Clayey sediments, where present, indicate more sluggish depositional settings. Palynostratigraphic analysis of drill-chip samples indicates the sediments were deposited during the Pliocene to Pleistocene. This contrasts with palaeovalleys in the eastern and southern Yilgarn where Eocene to Miocene sediments are prevalent beneath Quaternary infill. Pre-existing more ancient Cenozoic sediments in the Murchison palaeovalleys may have been eroded away by more recent dynamic river flow, although there is no substantiating evidence, and such sediments may have been removed to the Indian Ocean before or during the Neogene. Past river gradients in the Murchison Province were steeper than the low-gradient internally-draining systems in the east and south-east Yilgarn Miocene rejuvenation of the Murchison landscape may have deepened the valleys further after pre-Pliocene sediment had been stripped away.

Water quality and antiquity

Palaeovalley groundwater in the Murchison Province is generally less saline than in the southern Yilgarn, and is inferred to relate to the rainfall regime and the lithology and possibility to the fact that outlet to the Indian Ocean has periodically flushed salts from the Murchison valleys. Widespread 'stock quality' water suitable for mining and pastoral activities and some potable supplies are present. Groundwater salinity in Murchison project bores ranges from fresh to highly saline, 650–130 000 mg/l TDS, although it is mostly in the 1100–4600 mg/l range. The freshest water is from relatively shallow silicified calcrete aquifers. Hypersaline groundwater is present at greater than 100 metres depth down-gradient from Lake Annean (figure 2) in the Hope Palaeovalley, indicating leakage from the evaporatively concentrated playa lake brine pool. In contrast, Lake Austin appears to be more hydrologically closed as hypersaline groundwater emanating from beneath the salt lake does not appear to substantially flow down-gradient into the Sanford Palaeovalley. Topographic data also concur that there appears to be considerable segregation of Lake Austin from its host palaeovalley (figure 5).

Groundwater compositions are dominated by sodium and chloride ions (Na, Cl), typical for Australian arid-zone palaeovalleys studied elsewhere. Groundwater in many shallow bores exceeds the Australian Drinking Water Guidelines (ADWG) threshold of 50 mg/l for nitrate (NO_3), although not in the deeper project bores, suggesting sources from the biosphere (soil profile, termites, and nitrogen-fixing vegetation such as mulga). Some groundwater in the deeper bores exceeds ADWG thresholds for fluorine (F), boron (B), manganese (Mn), lead (Pb) and arsenic (As). Groundwater from both pre-existing shallow bores and many of the new bores has levels of uranium (U), approaching or exceeding ADWG thresholds. This is not uncommon for groundwater hosted in, or flowing from, Australian Precambrian granite terranes that are notably rich in uranium concentrations. The presence of elevated uranium concentrations in salt lake sediments is typical of these terranes and is revealed in radiometric imagery (figure 5).

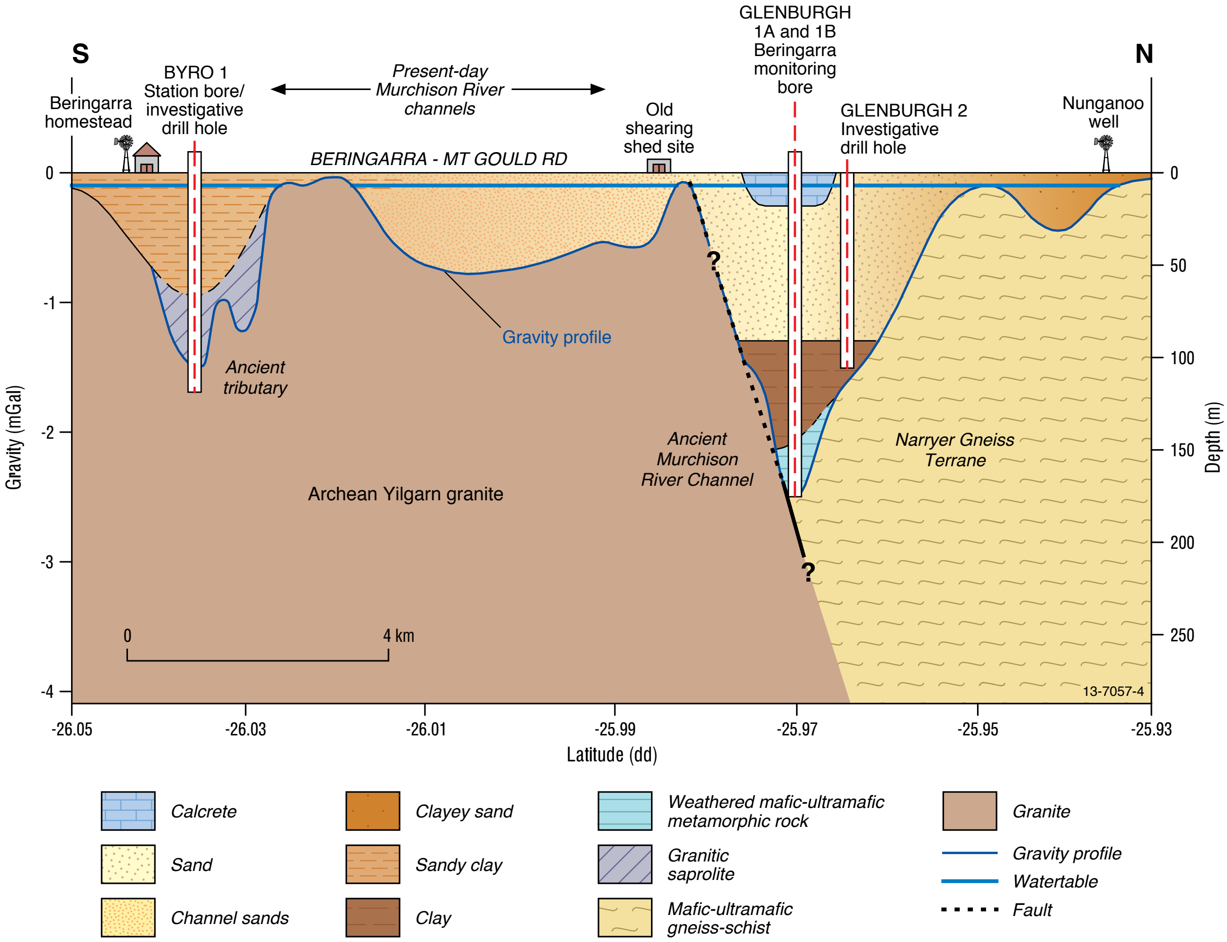

Figure 4. Cross-section across the Murchison River at Beringarra, immediately down steam from Jack Hills iron ore mine.

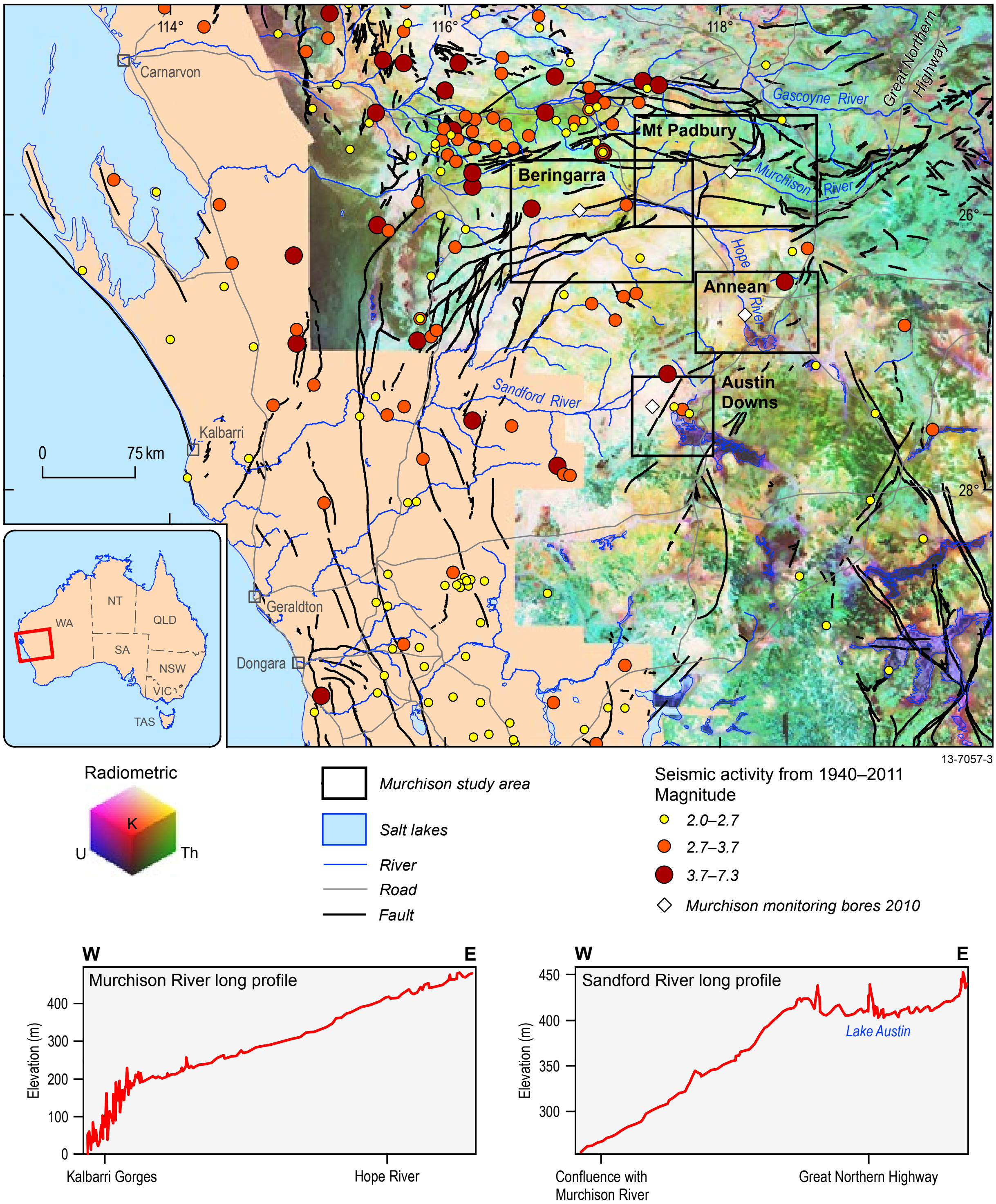

Figure 5. Radiometric image of the Murchison region with faults, seismic activity sites (earthquake centres), and project study sites, including the locations of monitoring bores installed for the Palaeovalley Groundwater project.

Stable isotope data from groundwater show groundwater in the new bores are enriched in the heavier isotopes. This indicates that evapotranspiration is the dominant process affecting groundwater systems. Radiocarbon (^{14}C) data indicate the presence of palaeowaters in the new bores, with percent modern carbon (pMC) ranging from 30 to 1.37 pMC representing uncorrected and uncalibrated ^{14}C ages of 9500 to 34 500 radiocarbon years before present (BP). Thus, all palaeovalleys contain palaeowaters. Recharge of the aquifers in the present climatic regime will need to be assessed from data loggers that have been installed in the new monitoring bores, although it is predicted that some minor periodic recharge occurs from rare high-magnitude rainfall events tracking east-south-east from the coast, from episodic river flow and percolating from semi-permanent pools in the main rivers.

Implications

Groundwater is more abundant in the Murchison than anticipated prior to these investigations because of the greater than expected valley depths and the high proportion of sandy infill, a combination that results in higher aquifer volumes. Data are insufficient to estimate yields and overall volumes for specific palaeovalley reaches or sites. Watertables are shallow (2.5–6 metres below ground level). Very substantial layers or lenses of highly permeable palaeochannel sands are up to tens of metres thick. This has been one of the most significant findings of the investigation, although it must be emphasised that the Murchison palaeovalleys are complex and heterogeneous and have thus far only been investigated at a reconnaissance level. Depending on connectivity between aquifers, groundwater extraction from these sandy aquifers may induce deleterious leakage from overlying sediments, from up-gradient palaeo-tributaries and from adjacent weathered and/or fractured bedrock that may either bring poorer quality water into the bores or deplete higher-quality aquifers elsewhere. Accordingly, further work is required to establish the extent and magnitude of such recharge and throughflow dynamics, and to determine analogies with better-known palaeovalley systems in the Eastern Goldfields. The available data suggest that palaeovalley reaches up-gradient of the salt lakes, that is, east of the Great Northern Highway, may provide relatively fresh groundwater for future town water supplies for Meekatharra, Cue and Mt Magnet and for mining developments in this part of the Murchison Province.

The Murchison demonstration study has shown that the application of efficient ground geophysical surveying and drilling techniques, combined with readily available DEM and regional geological and geophysical datasets, can effectively characterise palaeovalleys prior to more detailed follow-up work. This reconnaissance study has also highlighted the complexity and heterogeneity of the Murchison palaeovalley systems, emphasising the need for additional investigations, particularly coring of complete stratigraphic profiles (to bedrock) across the full width of palaeovalleys, and careful palynostratigraphic analysis. Long-term monitoring of bores is also required, particularly if large groundwater volumes are to be extracted to support expanding mining activities, to improve understanding of any potential variability and impacts in the groundwater systems.

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Water for Australia's arid zone—identifying and assessing Australia's palaeovalley groundwater resources: summary report
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