The Eastern Goldfields high-resolution seismic survey: preliminary interpretation and tectonic implications

by

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Introduction

The Geological Survey of Western Australia (GSWA) commissioned Velseis Pty Ltd to carry out a high-resolution seismic survey in the Kalgoorlie area, in Western Australia's Eastern Goldfields. The project involved the acquisition, processing and interpretation of seven 2D Vibroseis reflection lines with a total length of approximately 305 km. A preliminary interpretation of the seismic data was completed in August 2019 by Velseis, with input from GSWA geoscientists. The objective for the preliminary interpretation was to correlate major seismic features with interpreted structures from previous Geoscience Australia (GA) seismic surveys, and with GSWA gravity, magnetic and geological maps. Acquisition and processing information and a preliminary geological interpretation were summarized in an interpretation report that, together with the full package of geophysical data, was publicly released in September 2019 (available for download from <www.dmirs.wa.gov.au/geophysics>). This talk will concentrate on chief aspects of the recently acquired seismic data, from the perspective of the tectonomagmatic evolution of the Yilgarn Craton, with particular focus on the Kalgoorlie Terrane.

Tectonic evolution of the Yilgarn Craton

The Yilgarn Craton mainly exposes upper-crustal, Mesoarchean to Neoarchean granite–greenstone terranes. The Youanmi Terrane and the Eastern Goldfields Superterrane represent the two main crustal blocks of the craton (Fig. 1). Seismic and field data indicate that the whole craton includes a series of dominantly east-dipping, listric, crustal-scale shear zones (Zibra et al., 2014). At least some of these structures represent long-lived, transpressional shear zones that were active during the emplacement of syntectonic plutons in the 2730–2660 Ma time span (Zibra et al., 2014). The tectonic evolution of the Yilgarn Craton is controversial, with tectonic models ranging from arc accretion (Myers, 1995) to long-lived intracratonic settings (Van Kranendonk et al., 2013).

At the scale of the Kalgoorlie Terrane, recent structural studies have highlighted that this portion of the Yilgarn Craton was shaped during two major transpressional events (the terrane-scale D_1 and D_2). These events reflect bulk east–west shortening and took place at 2680–2660 Ma (Fig. 2), during the mature stages of the Neoarchean Yilgarn Orogeny. D_1 was associated with the development of the Ballard Shear Zone, a ≥200 km-long, north-striking transpressional structure that is exposed in the central portion of the terrane, north of the Kalgoorlie area. The Zuleika Shear Zone is interpreted as the southern continuation of the Ballard Shear Zone and represents the most prominent structure in the Kalgoorlie area (Fig. 3). The target area for the recent seismic survey is dominated by greenstone sequences that preserve a higher structural level than the northern portion of the Kalgoorlie Terrane, where more granitic gneisses are exposed. In the Kalgoorlie area, the northwest-striking Zuleika Shear Zone is associated with a dense network of subparallel, smaller-scale structures, which mainly nucleated along the steep limbs of kilometre-scale upright folds.

Preliminary interpretation of the new seismic survey

The mainly east–west oriented seismic traverses intersect the general northerly trend of regional structures at high angles (Fig. 3), offering favourable conditions for imaging the crustal architecture with its true across-strike geometry. For the purpose of this preliminary interpretation, we can identify a group of four main lithotectonic elements that are readily recognizable in both the geological map and seismic images. These include:

- a lower, dominantly mafic–ultramafic greenstone succession (Kalgoorlie Group) that generally produces prominent reflectors in the seismic images
- an upper, dominantly felsic greenstone succession that includes the Black Flag Group and remnants of younger, unconformable sedimentary sequences; these elements are generally transparent in the seismic images
- granites and granitic gneisses with intrusive contacts into the greenstones; granites are generally transparent in the seismic images, while pervasively foliated felsic gneisses might produce well-defined reflectors, particularly when they contain greenstone slivers
- Proterozoic mafic dykes, which are discordant with respect to Archean lithotectonic elements and may or may not produce prominent reflectors in the seismic images.

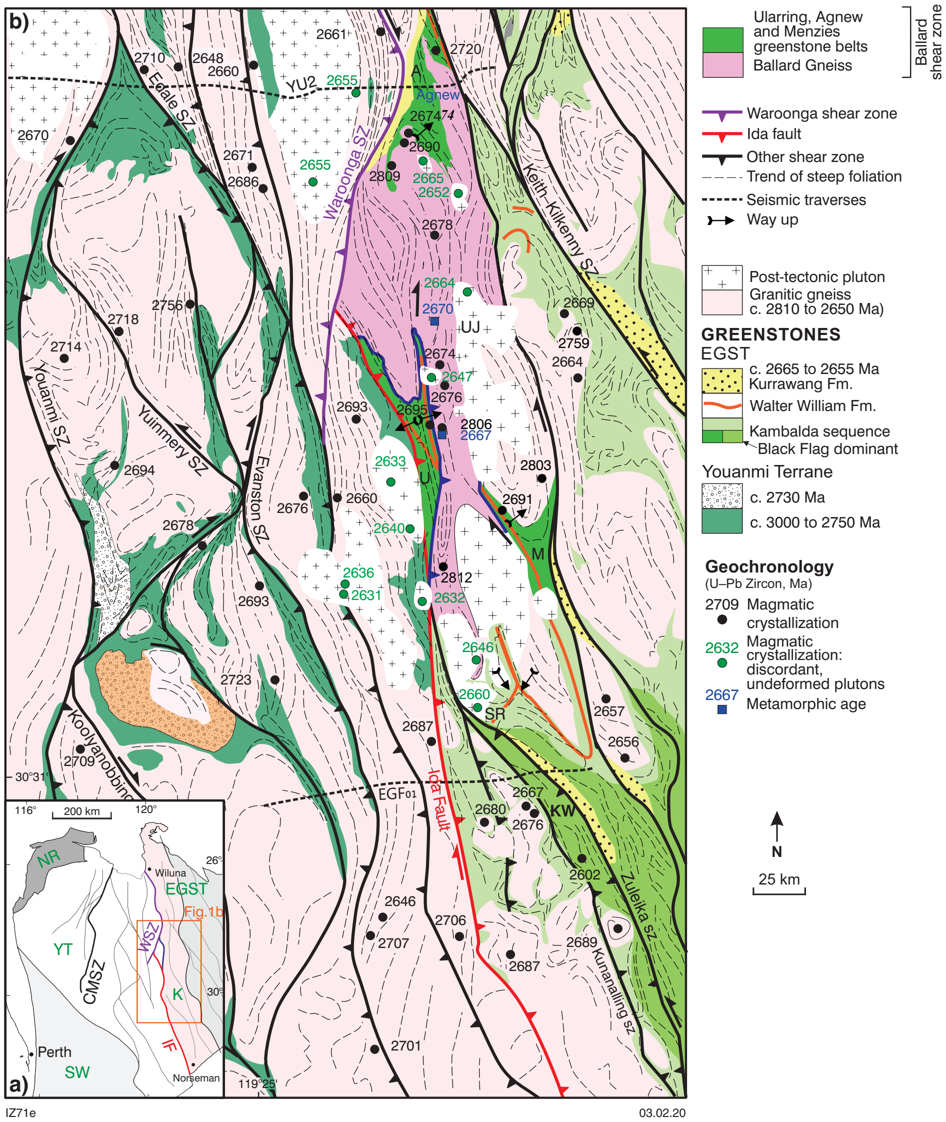

Figure 1. Geological maps of the western Yilgarn Craton: a) geological sketch map of the western portion of the Yilgarn Craton, showing the subdivision into the main terranes. Terrane boundaries are represented by craton-scale shear zones. The north-striking Norseman–Wiluna belt extends across the whole Kalgoorlie Terrane (in pink); b) interpreted bedrock geology of the central portion of the Yilgarn Craton. Note that both the Ida Fault and the Ballard Shear Zone are dextrally deflected along the Waroonga Shear Zone. The distribution of the Walter Williams Formation is after Hill et al. (1995). Ages of magmatic crystallization for granite plutons are from GA and GSWA databases. For all maps in this work, map compilation is based on combined field and geophysical data. Abbreviations: A, Agnew greenstone belt; CMSZ, Cundimurra Shear Zone; EGST, Eastern Goldfields Superterrane; IF, Ida Fault; K, Kalgoorlie Terrane; KW, Kurrawang Formation; M, Menzies greenstone belt; NR, Narryer Terrane; SR, Snot Rocks monzogranite; SW, South West Terrane; SZ, shear zone; U, Ularring greenstone belt; UJ, Union Jack granite; WSZ, Waroonga Shear Zone; YT, Youanmi Terrane

An additional ingredient (but not necessarily a lithotectonic element) that occurs in some of the seismic images is represented by patchy, transparent or poorly reflective areas that are generally discordant to the various domains, and can be preliminarily interpreted as zones of hydrothermal alteration. These zones might have been generated through intense fluid flow along structures and/or lithological boundaries. Examples of such potential alteration zones are along the Zuleika Shear Zone, at depths shallower than about 4 s (two-way time [TWT]), at the western end of Line 1, in the hanging wall of the Abattoir Shear Zone in Line 4, and along the Zuleika Shear Zone in Line 5. This preliminary interpretation suggests that most of the structures identified in map view can be consistently identified in most seismic profiles, down to a maximum depth of approximately 10 km below the currently exposed crustal level.

In the seismic images, the prominent reflectors generated by mafic–ultramafic portions of the Kalgoorlie Group define open folds that can be readily matched with corresponding structures identified on the geological map. Likewise, offsets and truncations of these prominent reflectors constrain the geometry of the major shear zones at depth. Other well-defined reflectors, morphologically similar to those attributed to the Kalgoorlie Group, are imaged in the deeper portions of most lines. These strong reflectors may correspond to tectonically buried portions of the Kalgoorlie Group, implying that the orogenic events produced important duplications of supracrustal units. Alternatively, they might correspond to remnants of the older greenstone successions, which are preserved in portions of the Kalgoorlie Terrane, or to other units that have not been recognized at the surface. Most of the shear zones that, at the currently exposed crustal level, are subvertical, show an overall listric geometry and commonly become shallow dipping below 2–3 s TWT. One of the most prominent structures in the area, the Zuleika Shear Zone (Fig. 3), is readily identifiable along the western portion of Lines 1, 2, 4 and 6, where it is imaged as an east-dipping listric structure representing the western boundary of the Kurrawang Formation (e.g. Fig. 3). This structure can be generally traced down to the deeper portions of most seismic images. The Zuleika Shear Zone is locally associated with, or displaced by, west-dipping, smaller scale structures that are generally confined to the upper 2–3 s of the seismic images. Results from the new seismic traverses are in substantial agreement with the larger scale image produced earlier by GA (Drummond et al., 2000), indicating that the Zuleika Shear Zone is oriented subparallel to the Ida Fault and can be traced down to lower crustal levels.

Field data indicate that most of the shear zones in the area exploit lithological boundaries, highlighting the role of competency contrast in localizing deformation in upper-crustal environments. This phenomenon introduces a degree of uncertainty in the seismic interpretation; in most cases it remains unclear to what degree the shape, thickness and other features visible in the images reflect the primary stratigraphic architecture, a tectonic overprint, or a combination of both.

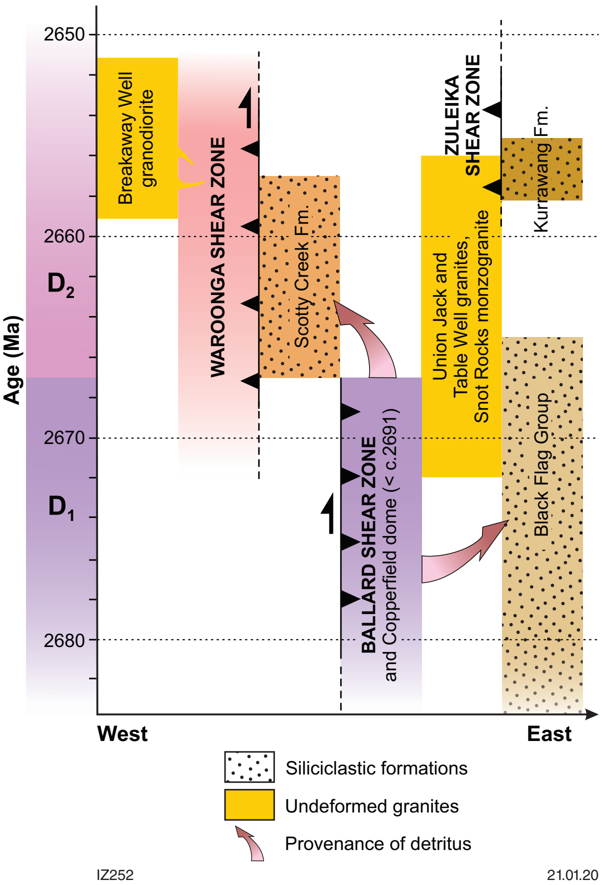

Figure 2. **Sketch illustrating available time constraints for development of the main structures in the study area. The different units are shown in an ideal east–west section, also detailing the type of contacts (intrusive vs tectonic)**

References

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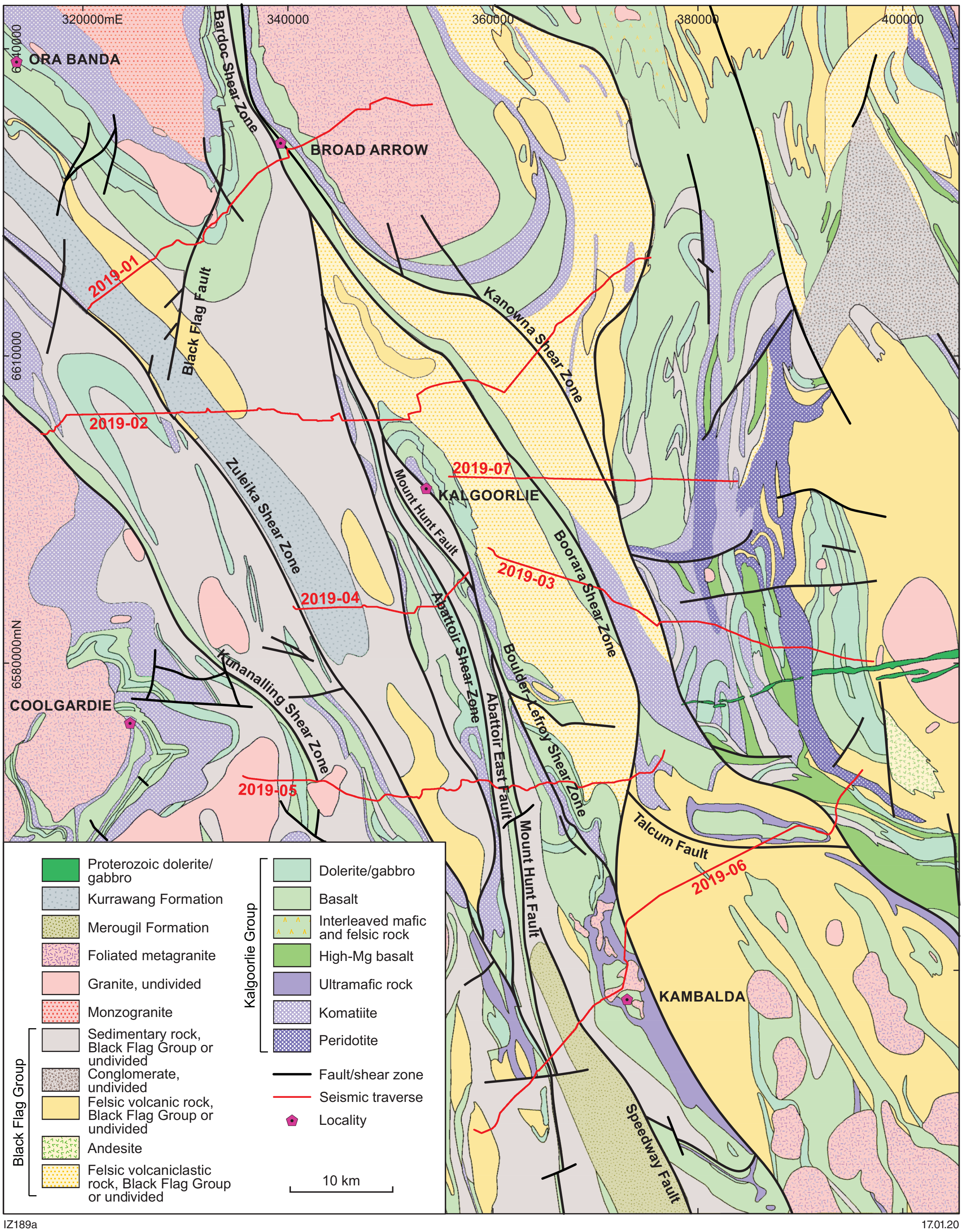

Figure 3. 1:500 000-scale geological map of the survey area. Grid references are MGA coordinates, Zone 51