Tectonic evolution and economic geology of the Paterson Orogen — a major reinterpretation based on detailed geological mapping

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Abstract

Recent mapping of the RUDALL and BROADHURST 1:100 000 sheets has provided considerably more detailed geological data than was previously available from reconnaissance investigations carried out in 1975–76. The new information has necessitated major reinterpretations of stratigraphy, structure, tectonic evolution, and mineral potential in this central part of the Paterson Orogen.

The oldest component of the orogen, the Rudall Complex, contains a foreland basin-type clastic succession divisible into five formations. The Pilbara Craton, which flanks and underlies the western side of the Paterson Orogen, collided with a plate of uncertain character (continental or oceanic) moving from the northeast, some time after 1780 and before 1500 Ma. As a result, the sedimentary succession was thrusted and overfolded from the northeast and east, metamorphosed to amphibolite facies, and extensively intruded by sheets of granite–granodiorite. Plate convergence continued spasmodically until about 1250 Ma, and was accompanied by late-stage, relatively minor felsic magmatism.

The Yeneena Group, which unconformably overlies the Rudall Complex, is a sandstone–shale–carbonate assemblage that was deposited between about 1100 and 850 Ma. Its depositional environments were regionally variable, and lateral stratigraphic relationships outside the RUDALL–BROADHURST area are still being examined. In the Broadhurst Range – Rudall River region fluviatile–deltaic deposition commenced in a northwesterly trending strike-slip basin system, with terrigenous supply coming from the southwest. The syndepositional strike-slip and oblique faults indicate broadly northeast–southwest compression, and the strike-slip regime is interpreted as a post-collisional response to continued plate convergence.

Infilling of the Broadhurst Range basin system was followed by widening of the Yeneena Basin and extensive carbonate deposition (Isdell Formation). At this stage, the basin deepened to the northeast, and only in the Telfer district are higher stratigraphic units now preserved. Transpressional upright folding and high-angle thrusting between about 900 and 700 Ma resulted in the main northwest-trending fold system (D_4) of the Paterson Orogeny.

Mineralization, mainly involving gold, copper (locally with lead and zinc), and uranium is chiefly syn-to post-Yeneena Group in age. Outside the Telfer area (still to be mapped at 1:100 000), most significant deposits and geochemical anomalies occur on, or in close proximity to, northwest to north-northwest striking faults. These structures are interpreted as syn-depositional strike-slip or oblique faults, reactivated during D_4.

KEYWORDS: Paterson Orogen, Proterozoic, Rudall Complex, Yeneena Group, tectonic evolution, plate tectonics, geological structures, stratigraphy, mineralization, thrust faults, strike-slip basin.

As discussed by Blockley and de la Hunty (1975), geological knowledge of the Paterson Orogen (referred to as a 'province' until 1990) was extremely limited prior to reconnaissance mapping at a scale of 1:250 000 by the Geological Survey of Western Australia between 1974 and 1976 (Chin et al., 1980, 1982). The conclusions reached from that work were first reported by Williams et al. (1976), and later expanded, using additional information, by Williams and Myers (1990). The main conclusions were:

(i) the Paterson Orogen consists of the Rudall Complex (igneous and sedimentary rocks metamorphosed to amphibolite facies) unconformably overlain by the Yeneena Group (clastic and carbonate rocks), which in turn is unconformably overlain by the Karara Formation (clastic and carbonate rocks);

(ii) the Rudall Complex has a long and complex history of multiple deformation and metamorphism, but contains two distinguishable units: older banded orthogneiss and paragneiss, and younger quartzite and schist;

(iii) the stratigraphic succession of the Yeneena Group is regionally variable due to deposition in three zones of differing palaeogeographic, tectonic, metamorphic, and igneous history.

Geological mapping of BROADHURST* and RUDALL (1:100 000) in 1989–92 has established that although the 1974–76 reconnaissance mapping was successful in identifying the

* Capitalized names refer to standard map sheets.

main stratigraphic features of the Yeneena Group, it was insufficiently detailed to adequately describe: (a) the geology of the Rudall Complex and, (b) the overall structural geology of the Paterson Orogen. Likewise, very little information relevant to the economic geology of the region and future mineral potential was provided.

Background information

Before describing the tectonic evolution of the central part of the Paterson Orogen, it is necessary to briefly review present knowledge of the stratigraphy and structure of BROADHURST and RUDALL (Figs 1 and 2).

Table 1 summarizes the Proterozoic stratigraphy of the BROADHURST–RUDALL area, but does not represent the stratigraphy of the entire orogen because of regional stratigraphic variations. Preliminary data from CONNAUGHTON (Bagas and Smithies, in prep.) reveal additional stratigraphic units in the Rudall Complex, and the Yeneena Group successions of the McKay Range, western THROSSELL, and the Telfer area are known to differ from that of the Broadhurst Ranges (Table 1).

Table 2 outlines the recognized episodes of deformation and metamorphism in the area. It should be noted, however, that D_2 deformation was not a single event, but probably involved spasmodic thrusting and folding over c. 100–200 million years. The complexity of D_2 is illustrated by the presence of distinct tectono-stratigraphic domains on RUDALL (Fig. 3). These domains are thrust-bounded slices of interfolded paragneiss and orthogneiss, which together form a 40 km-wide imbricate zone. Stacking and contact relationships indicate that north-eastern domains have overridden domains to the southwest.

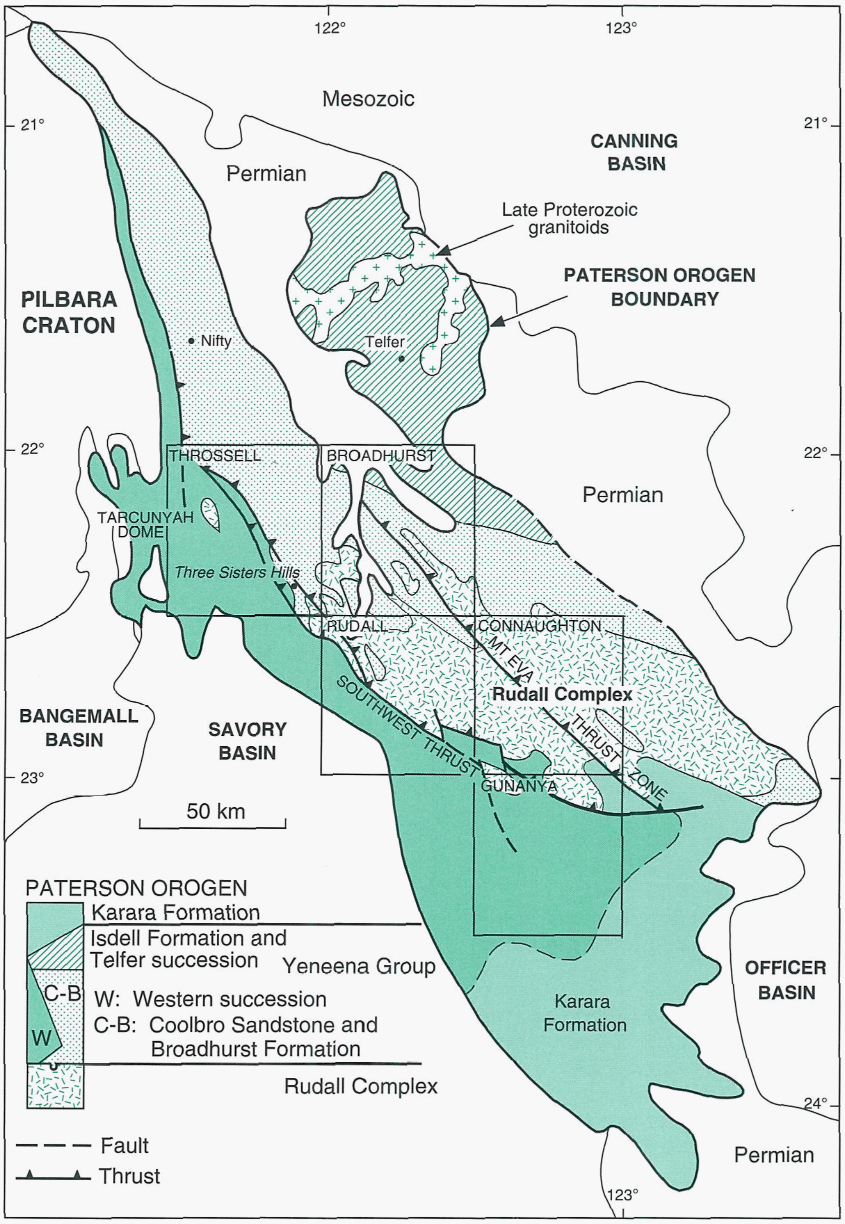

Figure 1. Location of mapped and partly mapped 1:100 000 sheets in the Paterson Orogen

Tectonic evolution

Rudall Complex

The first recognizable stage in the evolution of the Rudall Complex involved the deposition of a silici-clastic succession, approximately 5000 m thick, encompassing units from the Larry Formation through to the Butler Creek Formation (Table 1), probably prior to about 1780 Ma. The succession indicates shoreline–shelf–slope environ-ments in a subsiding foreland basin. The turbiditic Butler Creek Formation thickens eastwards, and the relatively shallow-water sand deposits of the Fingoon Quartzite become thinner to the northeast, implying the presence of a continent to the west during their accumulation. The local occurrence of a large amount of quartzofeldspathic sandstone in the Yandagooge Formation of northeastern RUDALL, indicates a source of feldspar-rich detritus to the northeast. Palaeocurrent evidence has been destroyed, and complex deformation on a regional scale makes palaeo-geographic reconstructions difficult. Nevertheless, the features are consistent with shallow-water deposition in a foreland basin on the eastern margin of a continent.

The lowest part of the Poynton Formation consists of well-sorted quartz sands and minor pebble beds, which comprise a

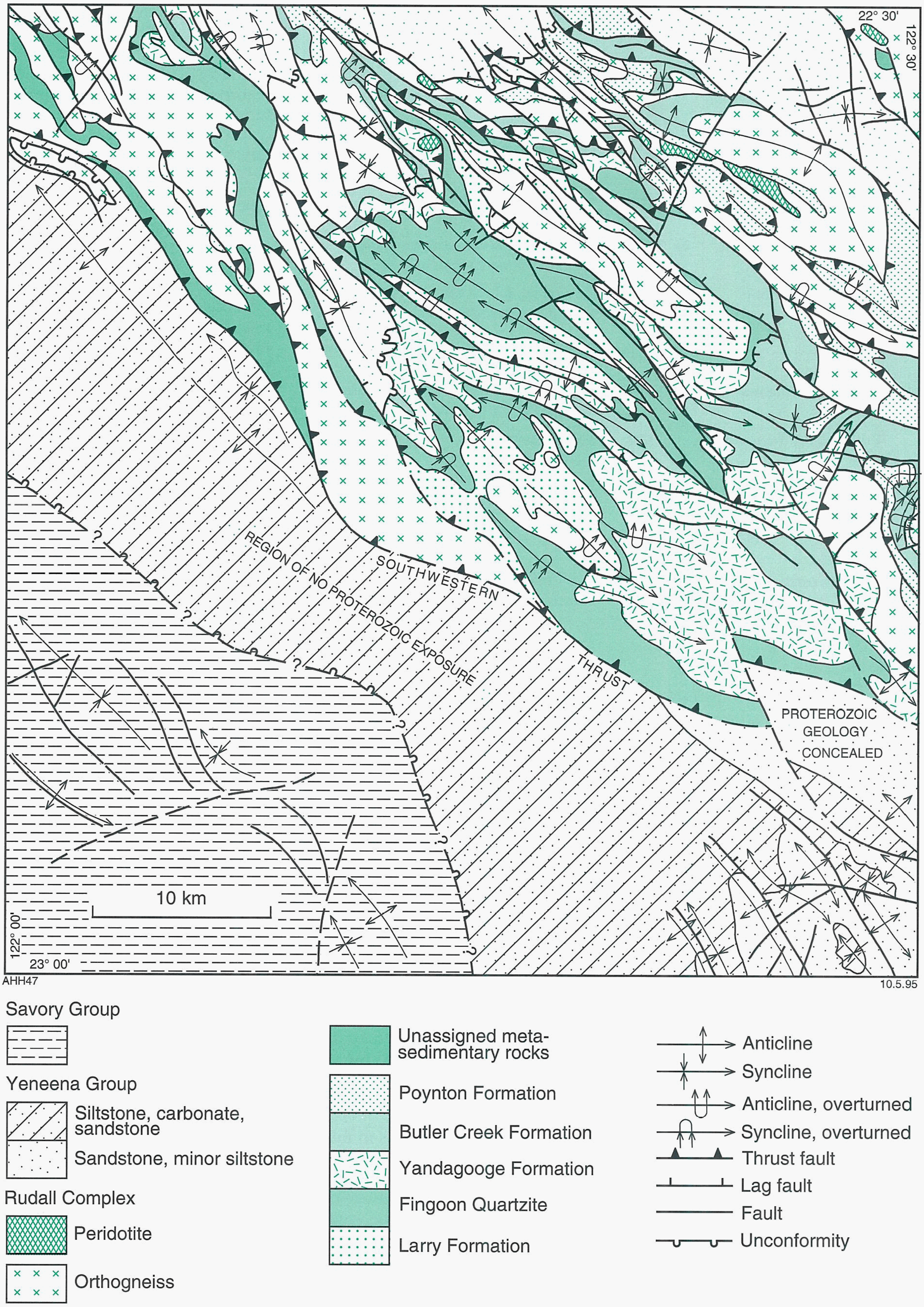

Figure 2. Simplified geological map of RUDALL, showing major structures and Proterozoic stratigraphy

Table 1. Proterozoic stratigraphy of BROADHURST and RUDALL, excluding the McKay Range succession (Yeneena Group)

	Stratigraphic unit	*Thickness (m)*	*Lithology*
YENEENA GROUP	Isdell Formation	>1 000	Limestone, dolostone, calcareous siltstone, and minor shale
	Choorun Formation	<2 000	Sandstone, siltstone, shale, conglomerate, and minor dolostone
	Broadhurst Formation	0 – 2 000	Shale, greywacke, sandstone, and minor carbonate rocks
	Coolbro Sandstone	0 – 4 000	Sandstone, minor siltstone, shale, and local basal conglomerate
~~ unconformity ~~~			
RUDALL COMPLEX	Poynton Formation	>1 000	Quartzite, psammitic gneiss, quartz–muscovite schist, minor BIF
	Butler Creek Formation	>1 000	Banded paragneiss, minor quartzite, quartz–biotite schist
	Yandagooge Formation	1 500	Pelitic to semi-pelitic schist, minor quartzite, and BIF
	Fingoon Quartzite	1 500	Quartzite, minor quartz–muscovite schist
	Larry Formation	>1 000	Psammitic gneiss, minor muscovitic quartzite

shallow-shelf facies quite distinct from the underlying turbidites of the Butler Creek Formation. This abrupt change is not associated with an angular unconformity, but a disconformity could be present. The Poynton Formation is thicker towards the east, but its stratigraphic top is not preserved, and thickness variations could be due entirely to a combination of thrusting and granitoid intrusion. Altered fine-grained units at some localities include metamorphosed felsic volcanic rocks or felsic volcanogenic sedimentary rocks. This indicates prior or contemporaneous felsic volcanism, but there are no volcanic remnants of a magmatic arc in the Rudall Complex. If such an arc existed it must have been situated to the east or northeast of RUDALL.

The most striking geological feature of the Rudall Complex is the widespread intrusive and structural interleaving of metasedimentary rocks and orthogneiss. Examination of the map reveals that, although detailed relationships are complex, two valid generalizations can be made:

(i) lithologically layered and xenolithic orthogneiss is almost entirely restricted to the western margin of the Rudall Complex, and

(ii) the K-feldspar-augen orthogneiss is mainly confined to sheets within the Yandagooge Formation – Butler Creek Formation section of the stratigraphic column.

This establishes that the lithologically layered orthogneiss occurs in the lowermost structural levels of the complex, whereas the K-feldspar orthogneiss has been preferentially emplaced at a higher structural level, probably along thrusts or shear zones.

The origin of the granitoids in the Rudall Complex is a subject requiring specialized geochemical investigation. As yet there have been no such studies in the region, and evidence is restricted to that from field observations. There is currently no evidence that any of the granitic orthogneisses represent up-thrusted Archaean or Early Proterozoic basement. Therefore, all are assumed to bear an intrusive relationship to the sedimentary succession, and most are probably genetically related to the orogenic belt. The Rudall Complex contains features consistent with a plate-tectonic regime, and its granitoids could be interpreted in terms of either magmatic arc or fold-thrust belt environments.

The western zone of lithologically layered orthogneiss with numerous enclaves of paragneiss, paraschist, and mafic–ultramafic rocks is intruded by the relatively homogeneous K-feldspar-augen orthogneiss. On RUDALL the layered orthogneiss contains both S_1 and S_2, but only S_2 has been recognized in the K-feldspar orthogneiss. Providing this is not merely a consequence of the general homogeneity of the latter (making S_1–S_2 distinction difficult), it can be inferred that the D_1 event (subhorizontal thrusting) occurred prior to crystallization of the K-feldspar orthogneiss protoliths. Thus, D_1 could have led to partial melting, and the intrusion of sheets of the K-feldspar granitoids into the layered orthogneiss and the metasedimentary succession.

The stratigraphic succession of the Rudall Complex on RUDALL contains no mafic volcanic rocks, but sheared serpentinized peridotite, associated with pelitic schist and turbiditic metasediments, occurs in three west-northwesterly trending zones. The assemblage is lithologically similar to compressed and attenuated ophiolitic units in many orogenic belts, such as the Cordilleran belt of western North America and the Himalayas (Windley, 1984). From a detailed study of the ultramafic units, Carr (1989) concluded that they represent slices of Proterozoic oceanic crust. On structural evidence it seems that rocks of the Rudall ultramafic zones originated northeast of RUDALL, and the assemblage is one which could have formed in a marginal basin environment. Such an environment could have been adjacent to the postulated northeastern volcanic-arc system.

The deformation and metamorphism assigned to D_2–M_2 indicate major collisional forces were in effect, probably, from the very limited isotopic data, sometime between 1750 and 1500 Ma. Overfolding and thrusting from the northeast and east were produced by an advancing plate (no remnants of this have yet been identified, but may be concealed beneath the Canning Basin). The extent of deformation suggests either continent–continent collision (Himalayan-style), or continent – oceanic crust collision in which the oceanic crust contained non-subductable accretionary terranes (Cordilleran-style). In the Sylvania Dome area, 250 km west-southwest of RUDALL, Tyler (1991) suggested a 2000–1600 Ma event of continent–continent collision occurred, producing north-northeast-directed thrusting against the southern margin of the Pilbara Craton. Therefore, it appears that the Early Proterozoic successions on the eastern and southern margins of the Pilbara Craton were sandwiched between two obliquely converging plates.

There is substantial isotopic evidence for an important metamorphic and felsic magmatic event during 1250–1100 Ma. Felsic intrusions have been dated at 1247 ± 5 Ma (crystallization age), 1132 ± 21 Ma (?metamorphic age), and c. 1080 Ma. On the south-eastern margin of the Pilbara Craton, sheared Archaean granitoids at Lookout Rocks provide Rb–Sr biotite ages of 1226 and 1194 Ma (de Laeter et al., 1977). This biotite forms part of a metamorphic foliation that is unconformably overlain by the Yeneena Group (Hickman, 1975; de Laeter et al., 1977). Williams (1992, p. 81) recorded tight, overturned, northwesterly trending folds in the c. 1300 Ma Manganese Subgroup of the Saltbush Range area, 70 km west of RUDALL, and these structures pre-date the unconformably overlying Yeneena Group (Williams, I. R., 1994, pers. comm.). The axial planes of the folds dip northeastward, indicating that the c. 1250 Ma event, like D_2, involved movement towards the southwest.

The c. 1250 Ma magmatic and metamorphic event may have been caused by raised isotherms associated with uplift and rapid erosion as the Pilbara and eastern plates moved closer together. Further thrusting probably occurred, but this would now be difficult to distinguish from earlier parallel thrusting (D_2).

Yeneena Group

The Yeneena Group unconformably overlies the Pilbara Craton (Archaean), the Rudall Complex (c. 2000–1200 Ma), and the Manganese Subgroup (c. 1300 Ma) of the Bangemall Group. It is unconformably overlain by the Savory Group (840–600 Ma; Williams, 1992), and is intruded by the Mount Crofton Granite (c. 620 Ma; Nelson, D., 1993, unpublished data). A considerable amount of largely unpublished isotopic data (Pb–Pb, K–Ar, and U–Pb; Hickman and Bagas, in prep.) indicate that hydrothermal events occurred between 900 and 700 Ma. In summary, present evidence, though by no means conclusive, indicates that deposition of the Yeneena Group took place sometime between 1100 and 850 Ma, and that the main episode of deformation (D_4), with accompanying hydrothermal activity, occurred between 900 and 700 Ma.

Table 2. Summary of deformation episodes on RUDALL and BROADHURST

Episode	*Major structures*	*Minor structures*	*Metamorphism and magmatism*
D_1: Regional layer-parallel shear, direction unknown	None identified	S_1: Penetrative layer-parallel schistosity; alignment of mica, quartz, and feldspar	M_1: Low pressure, mid-amphibolite facies conditions (not recognized on RUDALL 1:100 000); local melting; granitoid intrusion
D_2: SW- and W-directed thrusting and overfolding	Tight to isoclinal F_2 folds (axes trend WNW to N and are overturned towards SSW); D_2 thrust zones	F_2: Isoclinal folds S_2: Schistosity due to alignment of mica and quartz L_2: Stretching lineation within S_2	M_2: Medium-pressure amphibolite facies; some melting of pelitic rocks
D_3: Local W- or NW-directed isoclinal–recumbent folding	F_3 recumbent folds in Yeneena Group; axes E–W to NE–SW	Local faulting and quartz veining of the Rudall Complex – Yeneena Group unconformity	None identified
D_4: Regional deformation in response to SW-directed compression	Upright, tight to isoclinal F_4 folding about NW-trending axes; strike-slip fault system	S_4: Axial-surface cleavage inclined steeply NE L_4: Stretching lineations plunge down-dip on S_4	M_4: lower greenschist facies; locally intense cataclasis and dynamic recrystallization
D_5: Local deformation; ?NE-directed stress release after D_4	None identified	Open, recumbent F_5 crenulations; S_5 strike-slip cleavage	None identified
D_6: Brittle deformation in response to NNE–SSW compression	ENE and N-striking near vertical strike-slip faults	S_6: Strain-slip cleavage, axial to conjugate kink bands, deforming S_4	None identified

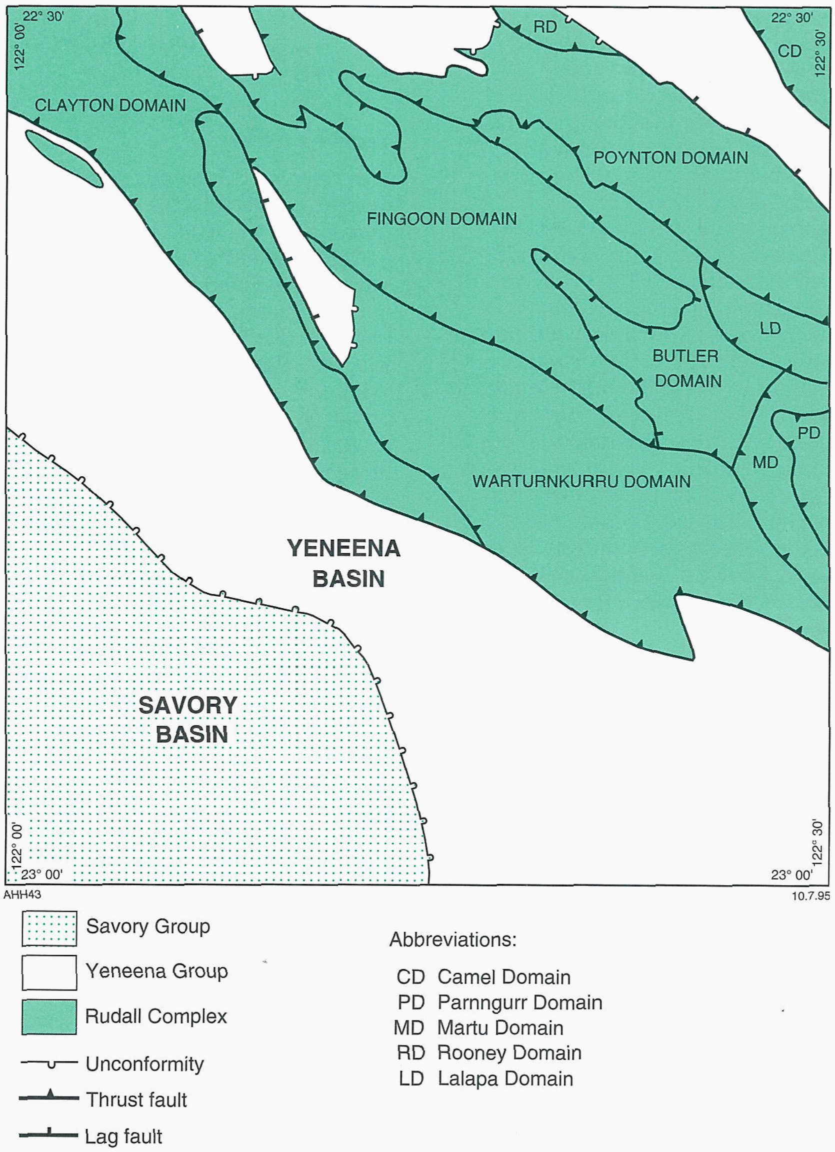

Figure 3. Major tectonostratigraphic units on RUDALL

In comparison with the geology of the Rudall Complex, that of the Yeneena Group is relatively simple. Structural modification is mainly confined to upright folding, and associated high-angle faults generally involve displacements of no more than 2–3 km. Metamorphic grade is low, and the succession is not fragmented by ubiquitous granitoid sheets. In fact, granitoid–pegmatite intrusion is absent, except in the northern part of the Paterson Orogen around Telfer.

Despite these differences, the Yeneena Group does have two important features in common with the Rudall Complex:

(i) The overall lithological succession is that of a continental margin. For the Yeneena Group, the interpretation that a continental landmass lay to the southwest is supported by abundant palaeocurrent data, and by lateral facies changes.

(ii) Deformation (D_4) included northeast–southwest compression, upright folding and thrusting from the northeast, and total crustal shortening by many kilometres.

These similarities suggest that the evolution of the Yeneena Basin marked a later stage in the progressive northeast–southwest convergence responsible for the Rudall Complex. Plate convergence was significantly retarded after the major collision during D_2 (in much the same way as collision reduced convergence of the Indian and Eurasian plates during evolution of the Himalayan orogenic belt; Windley, 1984). Plate collision impeded further subduction with the result that continued crustal shortening was mainly accommodated by strike-slip faulting. The Yeneena Basin developed as a strike-slip basin or, more probably, as a series of such basins.

On sedimentological grounds the sandstone–shale–carbonate succession of the Yeneena Group could be either a continental-margin succession or part of an intracontinental basin. The source of clastic detritus lay to the southwest and west, and the overall deepening of the basin was to the northeast. The succession has a basal conglomerate in most areas, and this commonly fills channels cut into the underlying basement. This is true not only along the present western and southwestern boundaries of the Yeneena Basin, but also in the Broadhurst Range, at least 50 km into the basin. Basal conglomerate is thin (commonly less than 10 m thick), and conglomerate is absent from the overlying fluvio-deltaic clastics of the Coolbro Sandstone. Thus, deposition in that part of the Yeneena Basin covered by BROADHURST and RUDALL commenced in a continental environment of stream channels and alluvial fans, and progressed, probably due to subsidence, to a deltaic – shallow-shelf environment.

The Coolbro Sandstone is absent from the 'Western Zone' (Williams, 1990), but reaches a thickness of at least 4000 m only 5–10 km into the adjacent Broadhurst Range area. In the BROADHURST–RUDALL area the boundary between these two zones of the Yeneena Group coincides with the Southwestern Thrust. A common feature of ensialic sedimentary basins is that normal growth faults (actively controlling deposition) can subsequently be reactivated with reverse movement during the tectonism responsible for basin closure (Mitchell and Reading, 1986). Thus, the southwestern margin of the Broadhurst Range basin was probably fault-controlled.

Palaeocurrent analysis of the Coolbro Sandstone on BROADHURST (Hickman and Clarke, 1993) revealed relatively uniform northeasterly to northerly currents flowed across the entire 1500 km^2 of outcrop. This flow regime continues onto northern RUDALL, except that in the east the currents were almost entirely northerly. These patterns are consistent with sediment supply from a continent to the southwest.

The Broadhurst Formation conformably overlies the Coolbro Sandstone, and has broadly the same regional distribution; it appears to be absent from the Western Zone succession. However, unlike the Coolbro Sandstone, this dominantly pelitic formation is most thickly developed in the eastern part of the Broadhurst Range. Instability during the early stages of deposition is indicated by graded turbidites, slump folding, and local conglomeratic sandstone units (Hickman and Clarke, 1993). Shale and intercalated carbonates of the Broadhurst Formation are generally carbonaceous and include stratabound sulfides. Anoxic deposition of black muds and sulfidic grey carbonates indicates a pelagic environment into which periodic turbidity currents carried mixed sand and mud from the basin margin.

Along its eastern boundary the Coolbro Sandstone – Broadhurst Formation succession is exposed only in the Mount Isdell area, where it is faulted against the Isdell Formation. Aeromagnetic data indicate that southeast and northwest from Mount Isdell the boundary is a structural discordance (either a fault or an angular unconformity).

The northwesterly-trending D_4 and D_6 faults of the Paterson Orogen exhibit both strike-slip and down-dip movement. The faults are curved and anastomosing, and break the area into lenticular, northwesterly elongated blocks. This type of pattern is characteristic of strike-slip regimes (Mitchell and Reading, 1986). In the Broadhurst Range – Rudall River area the curvatures and convergent relationships of the Southwestern Thrust and the Mount Isdell magnetic lineament would be consistent with strike-slip faults towards the northwestern end of a strike-slip basin (dextral movement).

The Western Zone succession is composed of shallow-water facies whereas the Broadhurst Formation is dominantly pelagic. The Western Zone includes shallow-water stromatolitic and microbially banded carbonates, reddish-brown siltstone and shale (commonly ripple-marked), rhythmically layered sandstone–siltstone–shale units, and local evaporates (halite pseudomorphs; Williams, I. R., 1994, pers. comm.). Black sulfidic shale and turbidites have not been recorded from the Western Zone. Differences between the two successions indicate that the Western Zone is a shallow-water, near-shore assemblage (marine or lacustrine), whereas the Broadhurst Formation is a deeper water facies to the northeast. In the RUDALL area the change from shallow- to relatively deep-water sedimentation occurs across the line of the Southwestern Thrust. The postulated growth fault along or just to the west of this line must have become submerged when deposition of the Coolbro Sandstone ceased. It is probably significant that the highest beds of the Coolbro Sandstone exhibit slump folding indicative of basin subsidence.

The Isdell Formation is of major importance in the Yeneena Group, but its stratigraphy and regional correlations are still poorly understood. In the type area around Mount Isdell (BROADHURST) the formation is chiefly composed of dark grey, sulfidic dolomitic limestone and dolostone, with subordinate silty pale grey-cream carbonate and shale. No stromatolites have been found, and the facies appears to be relatively deep-water in nature; however, in the Western Zone of THROSSELL, and on the northeastern part of BALFOUR DOWNS (1:250 000), Williams (1989, 1990) described the formation as a shallow-water assemblage of stromatolitic carbonate, clastic dolostone, sandstone and conglomerate, and dolostone containing scours and erosion channels filled by sandstone and conglomerate. If present correlations (Williams, 1990) are correct, the Isdell Formation passes from a near-shore, shallow-water unit in the west to a deeper water, partly anoxic carbonate unit in the east.

Deformation of the Yeneena Group occurred mainly during D_4, and produced northwest- and southeast-plunging, tight to isoclinal, overturned folds, with axial planes dipping steeply northeast. Most fold limbs are sheared and partly replaced by high-angle faults (thrusts and lags). Where fault planes are exposed they generally show more than one linear fabric, testifying to reactivation, usually during D_6. D_4 movement appears to have been down-dip, with lineations generally plunging between 50° north-northeast and 50° east. The folds themselves are arranged en echelon, and are here considered to be transpressional in origin. Such folds could be produced within a northwesterly trending strike-slip fault system, under either dextral or sinistral movement. In either situation, the maximum compressive stress was directed along an approximately southwesterly trend (± approximately 30°). Thus, the direction of crustal shortening during D_4 was similar to that during D_2. D_6 deformation involved north-northeasterly trending compression, with the dominant set of dextral strike-slip faults striking northwest to north, and a complementary set of sinistral faults trending east-northeast.

Mineral potential

Interpretations of depositional and tectonic settings contribute to the assessment of the mineral potential of a region, because particular types of mineral deposits are associated with specific geological environments. Table 3 summarizes the tectonic evolution of RUDALL, and suggests the types of mineralization which might be present.

The Paterson Orogen has proven potential for gold, copper–lead–zinc, and uranium mineralization. Additionally, mineral exploration and the recent mapping and accompanying geochemical investigations have indicated significant prospectivity for lead–zinc, molybdenum, bismuth, and possibly tungsten, nickel, chromium, and platinum-group element (PGE) mineralization.

Table 3. Summary of Proterozoic tectonic evolution on RUDALL, with theoretical metallogenic implications

Regime	*Phase*	*Environment*	*Unit/feature*	*Structure*	*Potential mineralization*
STRIKE-SLIP REGIME	D_6 late strike-slip	Brittle deformation	Quartz veins	Strike-slip faults and transpressional folds	Epigenetic Au in quartz veins
	Clastic deposition	Foreland basin	Savory Group		
	Erosion	Fold-thrust belt (inactive)	Unconformity		
	D_4 SW-directed movement and basin closure	Dominantly transpressional fold-thrust belt	Silicified shear zones	Upright to overturned, tight to isoclinal NW-trending folds and NE-inclined thrusts	Epigenetic Au in quartz veins; hypothermal base metals
	Stable carbonate shelf	NE-deepening shelf, gradual subsidence	Isdell Formation		Mississippi Valley-type, carbonate-hosted Pb–Zn (most potential in shallow-water facies)
	?Regional basin amalgamation	?Marine transgression	?Unconformity		
	Basin subsidence and enlargement to include Western Zone shelf	Western Zone: supratidal to shallow-water, locally fluviatile–deltaic; Broadhurst basin: rapid subsidence and pelagic deposition	Broadhurst Formation, Choorun Formation, Waters Formation, Gunanya Sandstone	Syndepositional NNW to WNW trending faults, dominantly dextral strike-slip but with accompanying vertical movement producing growth faults; slump-folding from basin margin	Near-shore facies: Sabkha-type Cu–Pb–Zn, Copper-belt-type Cu–Co Distal facies: McArthur River-type Fe–Pb–Zn
	Development of Broadhurst Range strike-slip basin	Dominantly transtensional basin, elongate NW–SE and deepening NE	Coolbro Sandstone		Unconformity-related vein-style U (with associated Cu, Pb, Bi, PGE, and Au) on, or close to, faults
	Deep erosion	Inactive fold-thrust belt	Unconformity		
SUBDUCTION REGIME	Retarded convergence	Post-collisional deformation; crustal thickening and melting	Microgranite, aplite, and pegmatite	Local NW-trending folds	U-enrichment in granitoids
	D_2 collision, SW-directed	Fold-thrust belt	?Syncollisional granitoids	Nappes, and NE- to E-inclined stacked thrust sheets	Greisen-related Sn–W, with Cu, Mo, and Li movement
	Widespread granitoid intrusion	Late- to post-D_1 partial melting (crustal thickening), or subduction-related magmatic arc	K-feldspar-augen ortho-gneiss protoliths	Sill-form granitoid sheets, associated dykes, pegmatite, and veins	Pegmatite minerals; granitoid emplacement-related hydrothermal Au
	Clastic deposition, local volcanism	Rifted shelf; adjacent volcanic arc	Poynton Formation		Sandstone: stratabound U Shale–BIF: sedimentary-exhalative massive sulfides
	D_1 subhorizontal tectonic interleaving	?Thin-skinned thrusting along fold-thrust belt margin	Lithologically layered orthogneiss	Layer-parallel shear zones	Tectonically emplaced and mobilized pre-existing deposits
	Granitoid intrusion	?Partial melting beneath rifted basin	Granitoid protoliths for lithogically layered ortho-gneiss	Sill-form granitoid sheets	Greisen-related Sn–W, etc. (but probably too fragmented to be economic)
	Clastic deposition, mafic–felsic volcanic rocks in areas to NE or E	Subsiding foreland basin with shore-line, shelf and slope environments; probable rifting; adjacent volcanic arc and marginal basin	Larry Formation, Fingoon Quartzite, Yandagooge Formation, and Butler Creek Formation		a) Shelf sand and mud: strata-bound sandstone-type U b) Carbonaceous mud and BIF: sedimentary-exhalative massive sulfides c) Ultramafic–mafic: serpentinite-hosted Cr, Ni, or PGE; meta-basalt-hosted Cyprus-style Cu–Fe

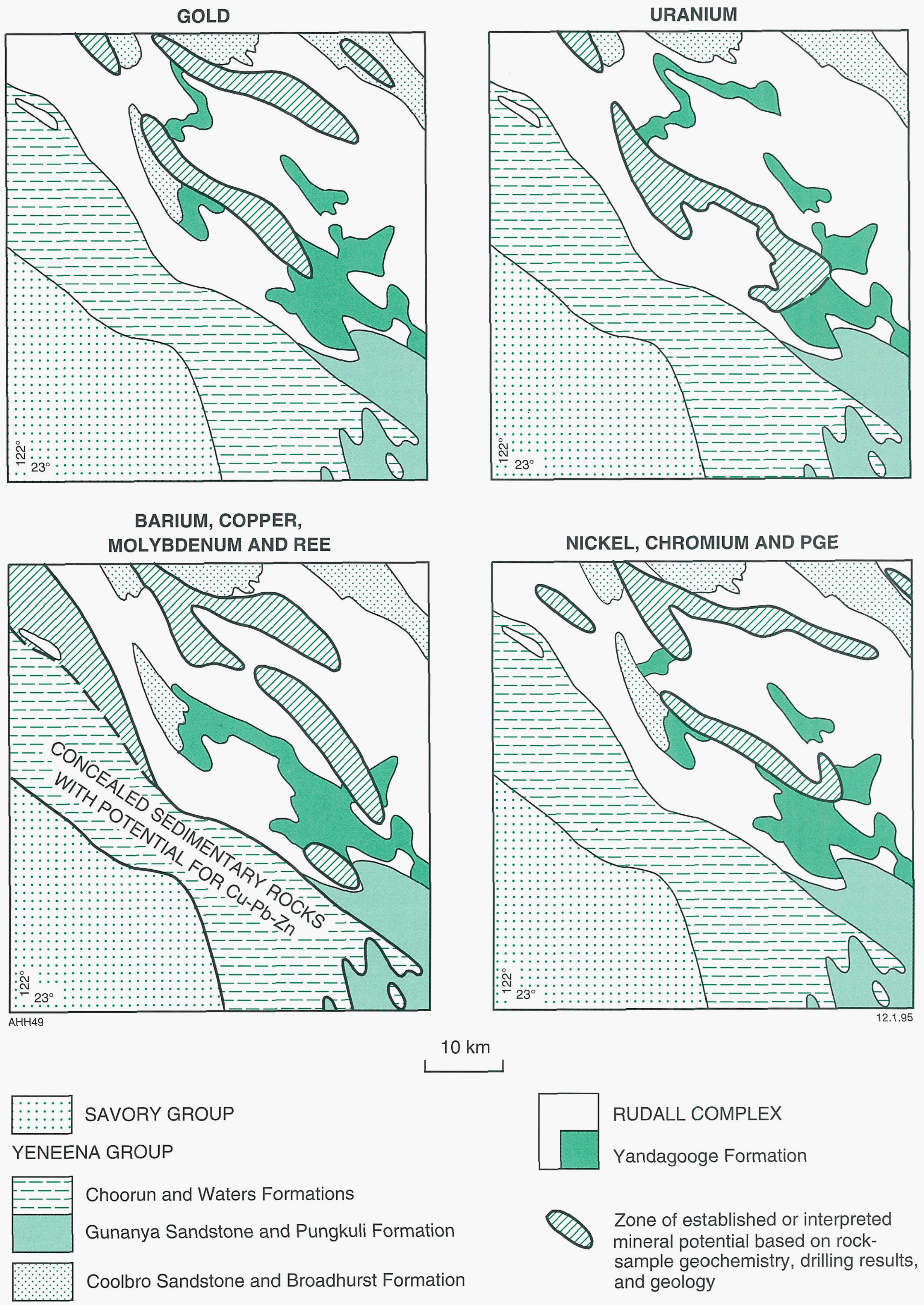

Figure 4. Summary of main zones of known and interpreted mineral potential on RUDALL

Figure 4 shows zones of mineral potential on RUDALL. Three northwesterly striking zones encompass all known significant gold anomalies. The central and southern zones coincide with D_4 faults in the Yandagooge Formation, and the central zone also encompasses mineralization of the Butler Creek and Poynton Formations.

Most of the gold mineralization is hosted by D_4 faults. The currently known deposits therefore appear to be syn- or post-D_4 in age, although because D_4 faults commonly coincide with D_2 faults, and probably also with growth faults formed during deposition of the Yeneena Group, the original age of gold mineralization is uncertain.

The northern zone of gold mineralization is confined to a shale–siltstone member of the Coolbro Sandstone and, if the mineralization is epigenetic, it clearly must be post-Yeneena Group in age; however, because gold mineralization is here associated with pyritic sediments, it could be syngenetic.

Uranium mineralization on RUDALL is confined to a relatively narrow northwesterly striking belt along the southwestern boundary of the Fingoon Domain. This belt is essentially a D_4 graben, and may have been a down-faulted block during deposition of the Coolbro Sandstone. Uranium deposits are hosted by fractures in the Yandagooge Formation, presumably not far below the level of the unconformity at the base of the Coolbro Sandstone. Figure 4 shows that uranium potential declines towards the southeast, based on the interpretation that the Coolbro Sandstone probably wedged out in this direction. Potential for uranium mineralization in the Poynton and Rooney Domains is considered to be low due to an absence of suitable pelitic or carbonate host-rocks close to the basal Coolbro Sandstone unconformity.

Nickel, chromium, and PGE mineralization may be present in the ultramafic rocks of the Rudall Complex, and PGE mineralization could be associated with uranium; however, most of the ultramafic bodies are small and fragmented, and the mineral potential of these units is therefore considered to be relatively low.

Figure 4 shows four zones with barium–rare-earth element–copper–molybdenum potential. The western zone, in the Clayton Domain, coincides with a belt of major D_4 thrusts and lags, but it is unclear to what extent these have acted as conduits for hydrothermal fluids. The northern zone partly corresponds to the central zone of gold mineralization (discussed above). Other shaded areas on Figure 4 chiefly involve the Yandagooge Formation and the upper Fingoon Quartzite where these units are dislocated by D_4 and D_6 faults. Although copper and molybdenum are commonly associated with one another, the absence of identified porphyry and the present deep erosion levels make it unlikely that mineralized porphyry-style systems have been preserved.

On RUDALL the Western Zone succession of the Yeneena Group is composed of shallow-water arenites, shale, and carbonate rocks. The succession occupies an area of about 1000 km^2 (Fig. 4), but is largely concealed and has not yet been explored. Geochemical investigation reveals local copper anomalies, and the belt is clearly prospective for Sabkha-type copper–lead–zinc, and possibly Copperbelt-type copper–cobalt or Mississippi Valley-type carbonate-hosted lead–zinc deposits.

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