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Coronation Hill U–Au mine, South Alligator Valley, Northern Territory: an epigenetic sandstone-type deposit hosted by debris-flow conglomerate

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Host rocks to the Coronation Hill U-Au mine have long been regarded as agglomerate occupying a volcanic vent, and, as such, the deposit has been regarded as volcanogenic and radically different from the other U-Au stratabound, unconformity-related deposits of the South Alligator Valley district. The 'agglomerate' is reinterpreted as a polymictic debris-flow conglomerate, consisting of rounded to angular clasts of quartz, quartzite, sandstone, carbonaceous shale, rhyolite, and volcaniclastics in a greywacke matrix. Its development was unrelated to volcanism. The deposit lies on the flank of a basinal conglomerate–sandstone–volcanic succession (Coronation Sandstone of the late Early Proterozoic El Sherana Group) that is unconformable on carbonaceous shale (Early Proterozoic Koolpin Formation). The ore surrounds an intensely faulted wedge-shaped area of conglomerate, altered volcanics, and carbonaceous schist. Uranium mineralisation is classified as epigenetic sandstone type, with uranium-enriched felsic volcanics as the source rock, sandstone beds as conduit rocks, and the carbonaceous schist, either as fault wedges or as clasts in the conglomerate, acting as reductant. In other deposits of the region, precipitation took place within in-situ carbonaceous shale faulted against the conduit sandstone. Intense chlorite alteration in the volcanics is unrelated to uranium mineralisation, but may be related to the gold mineralisation, which in places forms ore shoots that are separate from uranium ore and pass into the altered volcanics.

Introduction

The Coronation Hill mine is one of thirteen uranium-gold mines of the South Alligator Valley district, about 220 km southeast of Darwin in the Northern Territory (Fig. 1; Crohn, 1968; Crick & others, 1980). The deposits were discovered and operated from the mid 1950s to early 1960s. The ore consisted mainly of massive, vein-like, and disseminated pitchblende in carbonaceous shale and chert-banded siltstone in Early Proterozoic sediments (Koolpin Formation) of the Pine Creek Geosyncline. Lesser secondary uranium mineralisation occurred in sandstone and minor rhyolite and tuff (Coronation Sandstone, Pul Pul Rhyolite) of the late Early Proterozoic sequence, which is dominated by felsic volcanics and volcaniclastics (Needham & Stuart-Smith, 1985). This sequence separates deformed and metamorphosed metasediments of the Pine Creek Geosyncline from undeformed platform cover sediments (mainly sandstones) of the Middle Proterozoic McArthur Basin sequence further east, and is itself only mildly deformed.

The orebodies are mainly located on or near faulted contacts between Koolpin Formation and Coronation Sandstone or Pul Pul Rhyolite. Most workers favour ore genesis models that involve leaching of uranium from the felsic volcanics, movement of the uraniferous fluid along faults, and precipitation of uranium in carbonaceous and/or pyritic shale (Ayres & Eadington, 1975; Foy, 1975; Donnelly & Ferguson, 1980; Crick & others, 1980). However, the setting of the Coronation Hill mine is unlike that of the other deposits. It has been described by many workers as a volcanic vent, which would demand a significantly different model of ore genesis to that accepted for the other deposits of the district. This, and the rarity of uranium concentration in volcanic vents generally, led us to re-examine the geology of the Coronation Hill mine.

The study was conducted mostly before the discovery of the disseminated fine gold and platinum group elements (PGE) deposit in 1985 by a joint venture involving BHP Minerals, Noranda Australia and EZ, and therefore does not incorporate any data from that work. An outline of the geology of the gold body is given in the Noranda Pacific Ltd prospectus dated 27 June 1985. The gold is non-visible and finely disseminated in altered (quartz-sericite-minor chlorite) felsic volcanics of the Coronation Sandstone immediately east of the uranium-gold mine open cut.

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Previous investigations

Early development of the Coronation Hill mine was described by Allen (1954) & Gardner (1955). They described the host sequence as east-southeast-trending, generally south-dipping, altered volcanics, volcaniclastics, sandstone, and a polymictic sandstone-matrix conglomerate. Following mining in 1961-1962, Shepherd (1967) mapped the pit and outlined an area of 'highly fragmental agglomerate' occupying a 'volcanic fissure' about 20 m wide, trending roughly northeast across the east-southeast-trending sequence, and which hosted most of the ore. Subsequently, many authors of review papers of the district have unquestioningly described the host rock as volcanic breccia, and have embraced the volcanic vent concept, so that, by implication, a magmatic origin for the deposit has generally become the preferred model. Walpole & others (1968) nominated Pul Pul Hill and a site about 6.5 km east-southeast of Coronation Hill as additional volcanic vents. In 1976, a 201 m inclined hole was drilled beneath the mine workings by Noranda Australia Ltd to test for extensions of uranium mineralisation at depth (Coronation Hill diamond-drillhole CH3).

Whilst mapping the South Alligator Valley district as part of a 1:100 000-scale mapping project (Stuart-Smith & others, 1983), we paid particular attention to areas of suggested volcanic eruption, but could find no firm evidence that any of these sites were volcanic centres. Pul Pul Hill, like Coronation Hill, consists in part of rhyolite and polymictic conglomeratic breccia. The site 6.5 km east-southeast of Coronation Hill lies within granite; the location intended by Walpole & others is probably 1.4 km east of Coronation Hill, as shown on the 1 inch to 1 mile 'Geological map of the South Alligator River Valley' which accompanies their report. Here, rhyolite crops out, similar to that at Coronation Hill and Pul Pul Hill.

The only other evidence besides 'volcanic breccia' cited for volcanic vents in the district is from Shepherd (1960), who described 'horizontally disposed columnar jointing at Coronation Hill and Pul Pul . . . suggesting that vertical fissures in these two localities may have been the centres for lava extrusion'.

Geology of the Coronation Hill area

The area around the Coronation Hill mine (Fig. 2) consists of gently folded interbedded volcanics and sediments of the Coronation Sandstone (late Early Proterozoic El Sherana Group) resting unconformably upon tightly folded carbonaceous and ferruginous chert-banded siltstone and

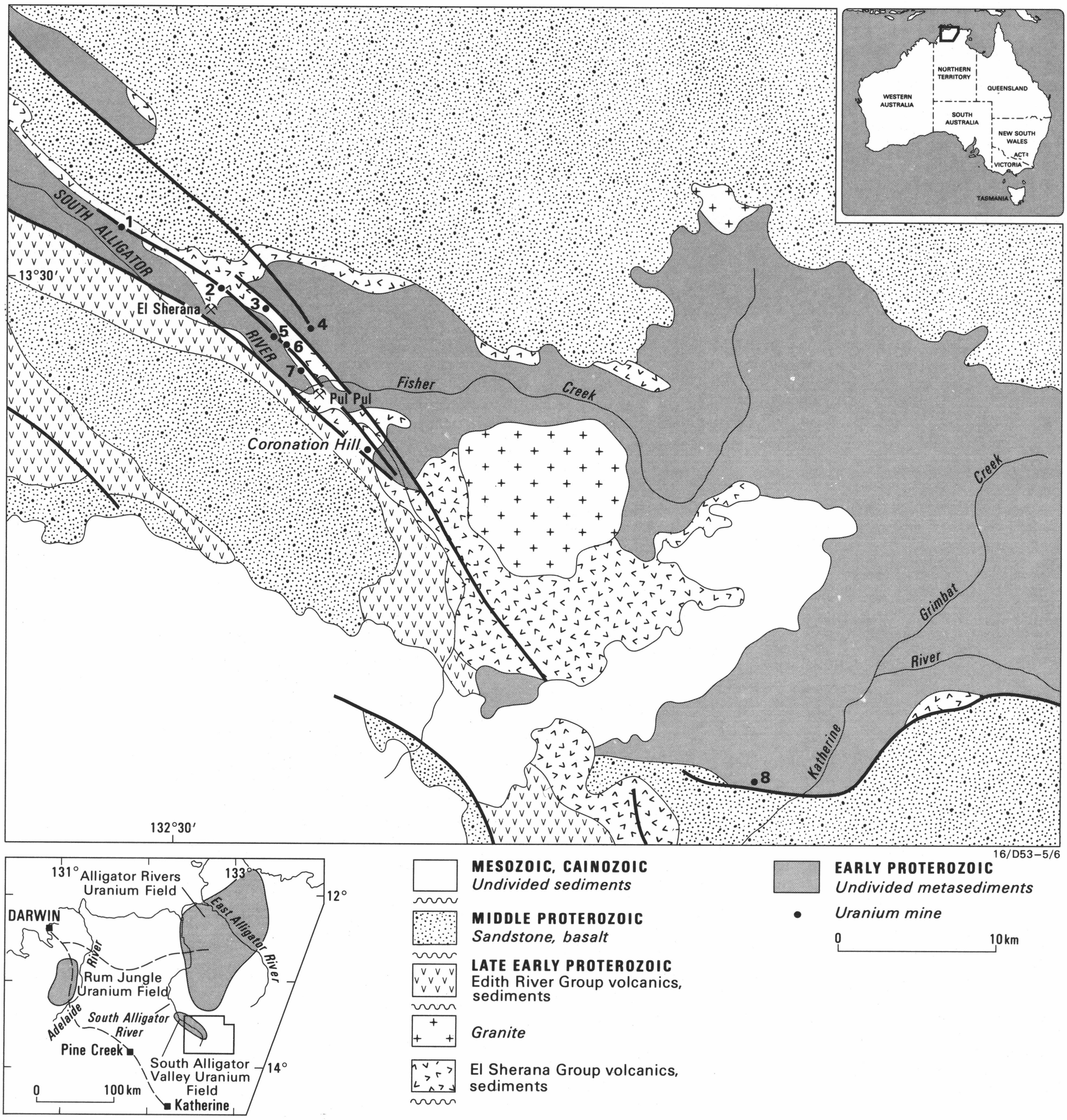


Figure 1. Coronation Hill mine location and regional geology.
1—Rockhole mine; 2—El Sherana, El Sherana West mines; 3—Koolpin mine; 4—Scinto VI mine; 5—Scinto V mine; 6—Palette, Skull mines; 7—Saddle Ridge mine; 8—Sleisbeck mine.

shale of the Koolpin Formation (Early Proterozoic South Alligator Group). During the hiatus which separated the Koolpin Formation and the Coronation Sandstone, a hematitic siliceous regolithic breccia was developed on and near exposed interbeds of stromatolitic carbonate within the Koolpin Formation. The top of Coronation Hill consists of this breccia (Scinto Breccia, El Sherana Group), which has partly slumped to rest in places on the younger Coronation Sandstone.

Units of the Coronation Sandstone define a basinal structure around Coronation Hill. The lowest unit (poorly sorted pebbly arkosic sandstone exposed near the banks of the South Alligator River) forms lenses up to about 70 m thick. Interbedded volcanics and volcaniclastics, including rhyolite, tuff, argillite, and shale, constitute the middle unit and overlie the sandstone apparently conformably. Dips are commonly erratic, suggesting syndepositional slumping, and flow layering in the autobrecciated, pale pink, finely porphyritic and commonly massive rhyolite is similarly unpredictable. Locally, south of the mine, this unit can be divided into an upper sequence about 50 m thick of rhyolite and minor tuff above about 100 m of interbedded tuff, argillite, siltstone, and rhyolite. Unpublished maps by United Uranium N.L. dated 1970 (geologist J. Harrison) suggest the presence of a distinctive green argillite about 50 m thick with minor tuff at the top of the interbedded sequence.

Black, highly chloritised, carbonate and quartz-veined massive rock with chloritised lath-shaped phenocrysts, probably of mafic composition originally, is present in mullock around the portal of the 900′ level adit. It may

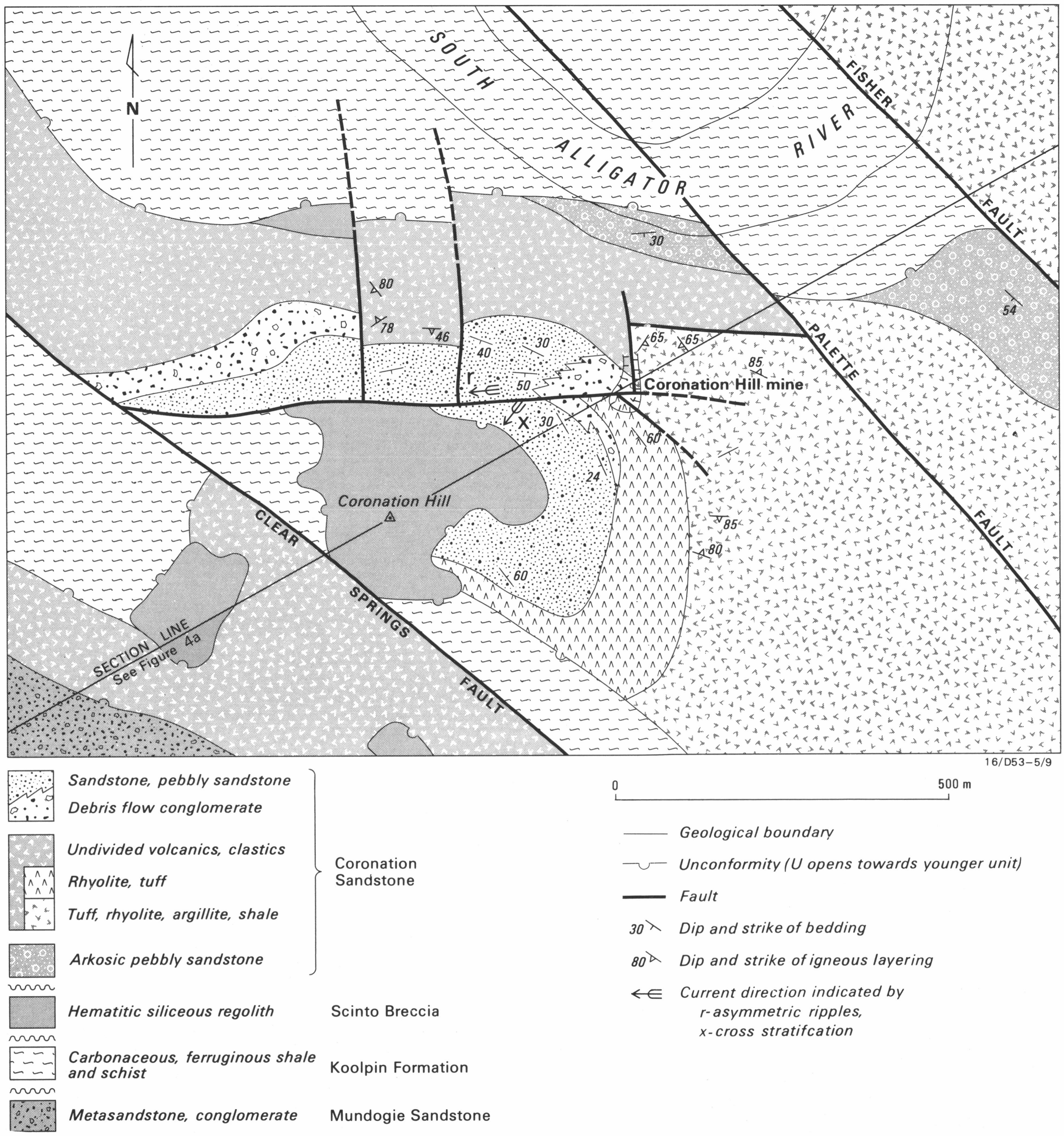


Figure 2. Geology of the area around Coronation Hill.
For explanation of symbols see Figure 9.

represent volcanics more mafic than the rhyolite, and is probably the same rock as that referred to as dacite (a 5 m body within tuff in the adit about 100 m from the portal) on unpublished plans of the mine workings prepared by D. Zimmerman & others of United Uranium N.L. in 1969.

The volcanic sequence is overlain apparently conformably by about 120 m of medium to coarse, ill-sorted, red-brown to purple sandstone, exposed mainly as cliffs. The sandstone is commonly pebbly with angular to subrounded vein quartz clasts: it is generally well bedded and in places cut by clastic dykes of disoriented angular bedded sandstone clasts in a sandstone matrix (Fig. 3). Minor asymmetric ripples indicate a west to southwest current direction. Polymictic conglomerate near the base grades laterally and upwards into quartz cobble conglomerate and sandstone. The polymictic conglomerate is similar to the vent breccia of the open cut, containing clasts mainly of vein quartz, silicified pale grey ill-sorted medium to very coarse lithic sandstone, ferruginous carbonaceous shale, and massive pink or cream rhyolite.

Many steep faults cross the area. The curvilinear faults of the open cut are splays from easterly and northerly trending fault sets that form a conjugate set between major northwest-striking faults, which dominate the structure of the South Alligator Valley district. A schematic section showing the setting of the Coronation Hill deposit within the basinal structure locally defined by the Coronation Sandstone is shown in Figure 4.

Description of the 'vent breccia'

The polymictic rock at Coronation Hill and Pul Pul Hill, described variously as conglomerate, breccia, and agglomerate

Figure 3. Clastic dyke in bedded pebbly sandstone of Coronation Sandstone, 400 m west of open cut.
Wallaby droppings 2 cm diameter.

by earlier workers, is a light grey, weathering buff or white, very poorly sorted, clast-supported melange of angular to well-rounded granules, pebbles, cobbles, and boulders of a range of volcanic and sedimentary lithologies in a variable matrix. The matrix is dominantly a pale grey coarse sand with minor medium to fine sand-grade pale grey to green-grey quartzose (and in places micaceous) greywacke (size grades are from Pettijohn & others, 1973). We examined material from the Coronation Hill open cut and from Noranda's drillhole.

Texture

Grainsize ranges from about 0.005 mm in the clay fraction to a maximum observed clast size of 1.32 m (greatest dimension). The size frequency distribution of grains defines three populations (determined by integration of microscopic point counting, visual estimates of crushed samples, grid analysis of outcrop photographs, and direct measurement of clasts in outcrop) (Fig. 5a): a matrix of medium sand to clay grade—about 10 per cent of the total rock (population A), a dominantly very coarse sand to granule population—about 40 per cent (population B); and a pebble to boulder population—about 50 per cent (population C).

Roundness of grains is related to the polymodal grain size (Fig. 5b). The matrix is typified by angular to subangular grains (at least in the determinable fraction coarser than about 0.03 mm), whereas the coarser populations (B, C) range from angular to rounded; a high proportion of well-rounded grains is present in population C.

Grain shape is difficult to determine for the whole range of size fractions, owing to the consolidated nature of the rock. However, pebble, cobble and boulder shapes were estimated on irregular outcrop surfaces, and by observation of sections cut through drill core; crushed matrix samples were also examined. Equant grains occur throughout the range, as do oblate or tabular grains except for the coarsest (>1024 mm) and intermodal pebble (916–32 mm) fractions. Prolate grains were observed only in the more dominant (over 8% of total rock) size fractions in B and C populations.

Composition

The composition of clasts indicates a heterogeneous provenance containing metamorphosed and unmetamorphosed sediments, and felsic volcanic rocks. About 48 per cent of clasts are non-volcanic.

Quartz, quartzite, and quartz sandstone are present as clasts in much the same amounts in both B and C populations (Fig. 5a). The clasts are generally rounded to well-rounded, and equant tending to prolate. The quartzite is highly strained with a strong planar fabric, indicating a metamorphic origin. Quartz grains in the sandstone are medium to coarse, unstrained, sub-rounded, and moderately to well-sorted, indicating derivation from a mature, unmetamorphosed source rock. Quartz in the matrix is generally highly angular and commonly tabular, but some larger grains are equant

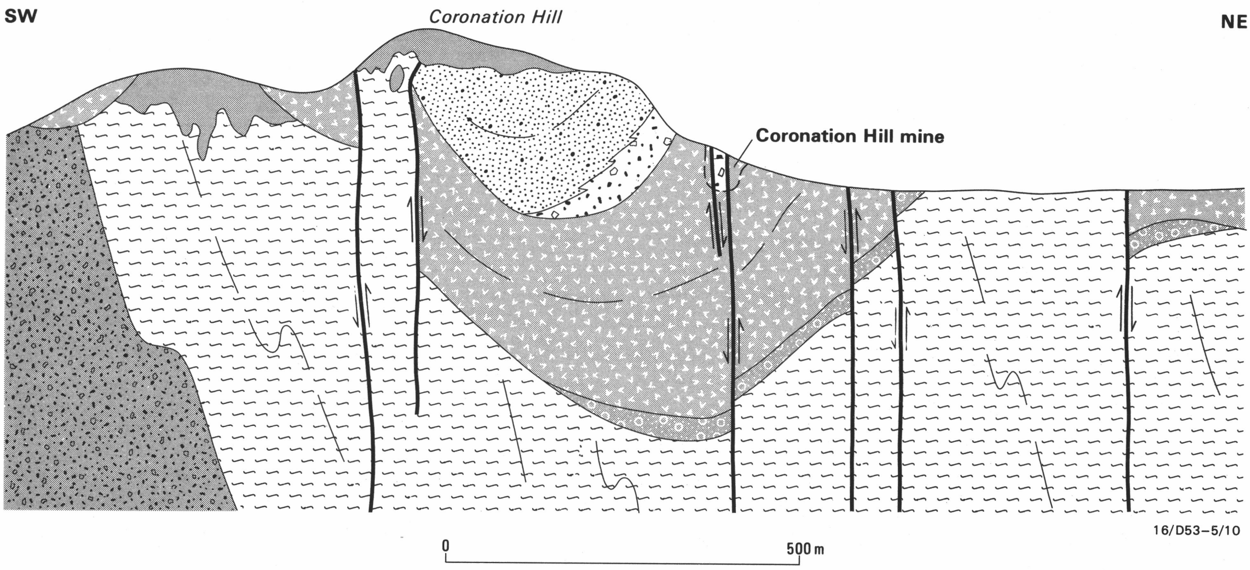


Figure 4. Schematic section through Coronation Hill area.
Vertical exaggeration about 1.5. Figure 2 shows section line and stratigraphic legend.

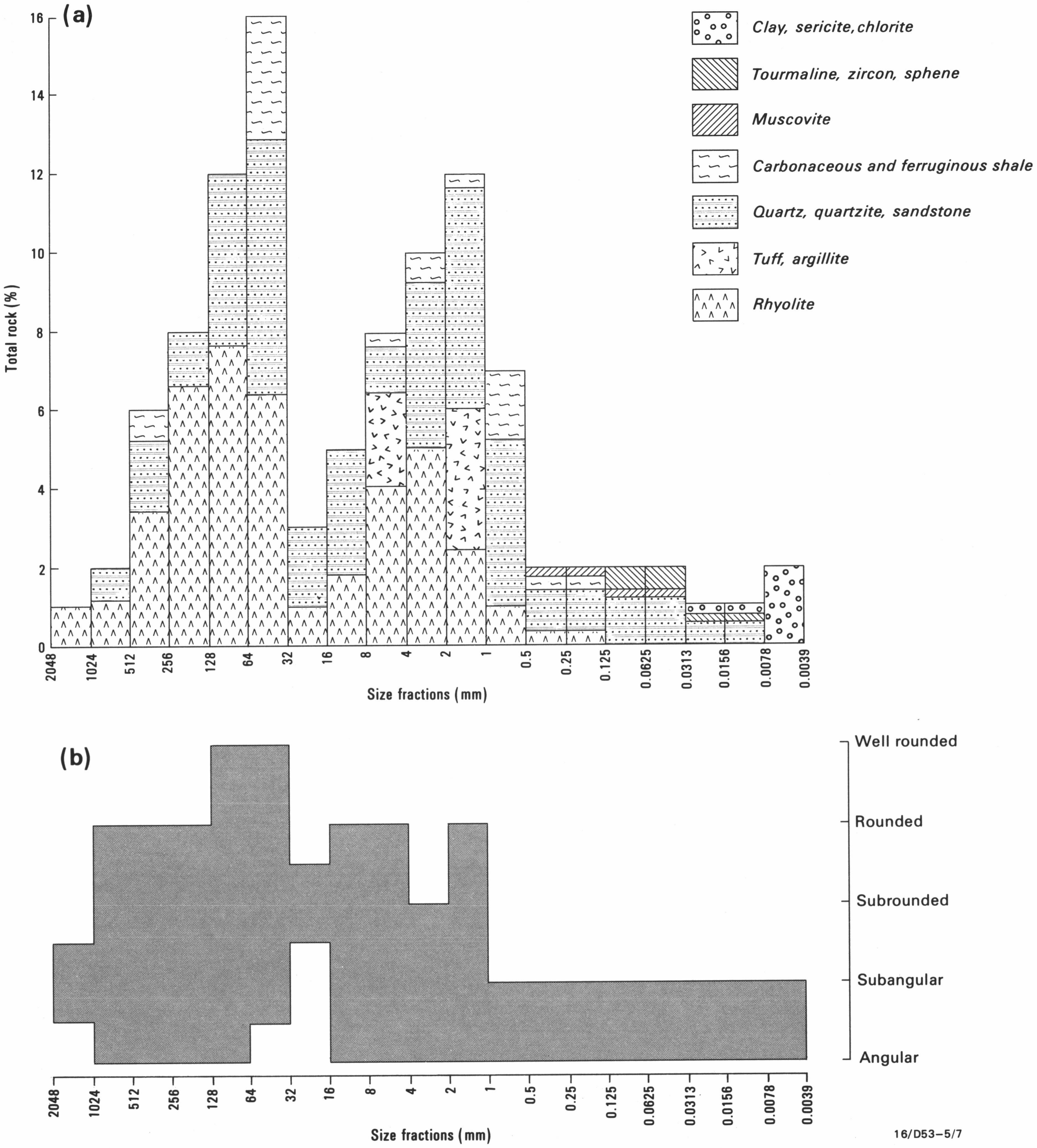


Figure 5. Mechanical composition of the debris-flow conglomerate. (a) frequency distribution of size fractions and lithological components of each size fraction; (b) clast shape variation by size fraction.

with subangular to subrounded shapes reminiscent of the euhedral quartz phenocrysts within many of the volcanic clasts. Syntaxial overgrowths are common on these and other larger, mainly rounded quartz grains.

Variation in the amount of volcanic clasts almost entirely accounts for the rock's pronounced polymodal character (Fig. 5a). The clasts are mainly pink or grey very fine rhyolite, composed almost entirely of interlocked quartz with scattered quartz phenocrysts up to 2 mm long. The rhyolite is commonly finely brecciated and weakly and irregularly altered to chlorite. Other volcanic rock types are dark grey massive to banded tuff and green/grey massive argillite. The volcanic clasts are with rare exception angular or subangular; equant shapes are most common, but tabular forms are widespread and prolate forms are evident in both populations B and C. Tuff and argillite are confined to the finer of these two populations, reflecting their less competent character.

Alteration and brecciation

All clast lithologies and the matrix display pervasive alteration to sericite and very pale green chlorite. About 25 per cent of the matrix clay fraction from 0.007 to 0.03 mm and all of it in finer grades is composed of these alteration minerals, which are interpreted to have developed from primary depositional clay particles. In volcanic clasts, mafic minerals are replaced by chlorite aggregates and feldspar phenocrysts are totally sericitised, and there is patchy Fe oxide, carbonate, quartz, and sphene (or leucoxene?) alteration. In places, sericite cuts across the chlorite aggregates. The sandstone clasts contain sericite completely replacing feldspar and radiating clusters of pale green chlorite after quartz. Fe oxides are restricted to near-surface, where they are formed by oxidation of chlorite.

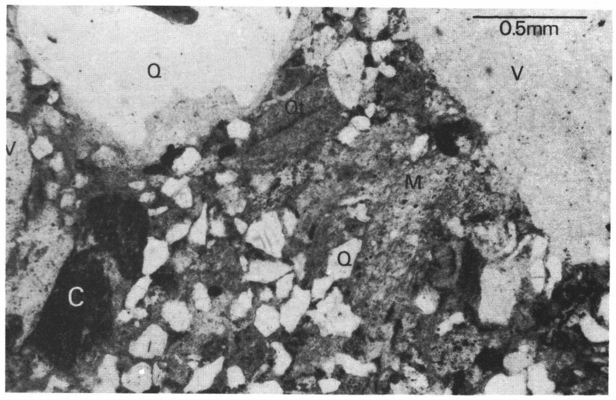
Minor veinlets of quartz cut clasts and matrix and are commonly lined by thin selvages of dark green chlorite aggregates. Patches of dark green chlorite also occur in the rock near the quartz veins. The probable paragenetic sequence is: pervasive sericite + pale chlorite → remobilised sericite → quartz + dark chlorite

Nearby exposures of rocks from which the clasts may have been derived are much less altered, and feldspar and mafic minerals are commonly preserved, suggesting that even the early sericite-chlorite is post-depositional. Weak alignment of matrix sericite may have been induced by crystallisation during diagenetic compaction.

All the rhyolite clasts show fine brecciation, evident in hand specimen as fine irregular fractures commonly tinted pale green. The fractures are pre-alteration, and do not extend into the matrix or clasts of other compositions. They are thus pre-depositional and probably a result of autobrecciation.

Carbonaceous or ferruginous shale fragments are entirely angular or subangular and tabular, and are similar in size distribution to the volcanics, although in each fraction they represent only a small proportion of the whole rock.

Detrital euhedral to subhedral grains of muscovite up to 0.5 mm long, and zircon, tourmaline, and sphene up to 0.1 mm are scattered through the matrix. Clay-like minerals form a fine felted groundmass in the matrix.



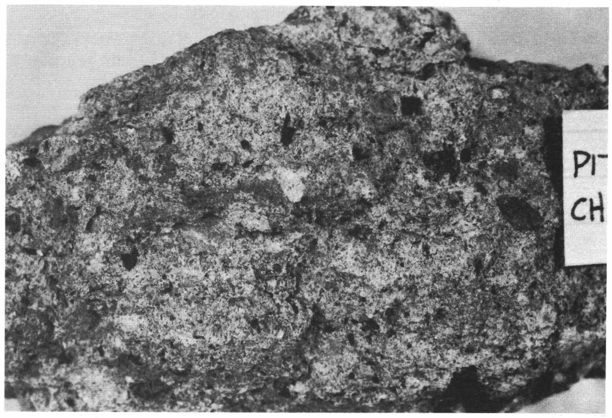


Figure 6. (upper) Photomicrograph of the polymictic debris-flow conglomerate:
Q—quartz, Qt—quartzite, V—felsic volcanic, C—carbonaceous shale, M—chlorite-sericite matrix flecked with equant iron-rich, and elongate carbonaceous, opaques. Note angular to subangular quartz grains, large embayed quartz grain derived from phenocryst with rhyolitic groundmass attached, scattered foliated pelite and quartzite clasts.
(Lower) angular carbonaceous slate fragments in ill-sorted coarse to pebbly greywacke matrix of the debris-flow conglomerate. Card is 2 mm high.

Sedimentary structure

The rock is essentially structureless, with random fabric orientation and no gross sorting or grading of clasts (Figs 6–7). However, at 3 localities in the pit exposure, single beds, 8–10 cm thick, of graded sandy granular to silt-grade matrix are present (Fig. 8). Within them, structure is restricted to crude lamination parallel to bedding in the silt grade. Both clasts and matrix range from coarser nearer the base to finer near the top. The tops of the beds are sharp and overlain by massive conglomerate, which, within 50 cm stratigraphic interval, contains clasts up to 16 mm across.

Geometry

Owing to poor exposure and faulting, the geometry of the 'vent breccia' is difficult to reconstruct. Shepherd (1967) indicated a north-northeast-trending, steeply dipping body, about 10–15 m wide, on the west side of the Coronation Hill mine open cut. Our work indicates a stratigraphic thickness of at least 20 m and possibly more than 40 m, thickest in the open cut or immediately west of it, and rapidly thinning to the west and southeast. The upper contact is gradational into overlying sandstone of the Coronation Sandstone, and the lower contact—unexposed except at faulted contacts—is apparently conformable on volcanics of the same formation. The 'vent breccia' appears to form a channel-like body roughly perpendicular to the present northwest strike of the Coronation Sandstone near the mine, and sedimentary structures in the overlying sandstone suggest current directions from the northeast (Fig. 2).

Interpretation

The 'vent breccia' displays few of the characteristics of a pyroclastic rock. The only volcanic rock to contain such a high proportion of non-volcanic clasts is hydrothermal explosion breccia, but the absence of intense hydrothermal alteration precludes this origin (Nairn & Wiradiradja, 1980). The lithological character of clasts and matrix and the presence of indisputable sedimentary structures, such as graded beds, indicate the rock to be a polymodal epiclastic sedimentary rock. The matrix is fine to medium-grained, lithic, angular, poorly sorted quartz-dominant greywacke. The range in lithology, size, roundness, and shape of clasts indicates an extraformational origin. Minor interludes when current waned to low energies are indicated by rare graded beds as fine as silt grade, and the rapid return to pebble-grade clasts above the graded beds suggests rapid energy fluctuations. Such unsorted, massive sedimentary deposits are common in both alluvial and deep-sea fan environments, and are interpreted as debris-flow deposits (e.g. Bull, 1972; Heward, 1978).

The clast-supported, clast size and sandy matrix characteristics indicate a laminar grain flow transport mechanism with grains supported by dispersive pressure, and deposition by 'frictional freezing' as a consequence of frictional grain resistance (Lowe, 1982). Sediments of this type, deposited from cohesionless flows (also termed 'density modified grain flows'; Lowe, 1976) typically consist of clast-supported pebbles and cobbles set in a poorly sorted sand, silt and clay matrix in beds of >0.4 m (Lowe, 1982).

The absence of grading or inverse grading indicates relatively low dispersive pressures during sedimentation. The two

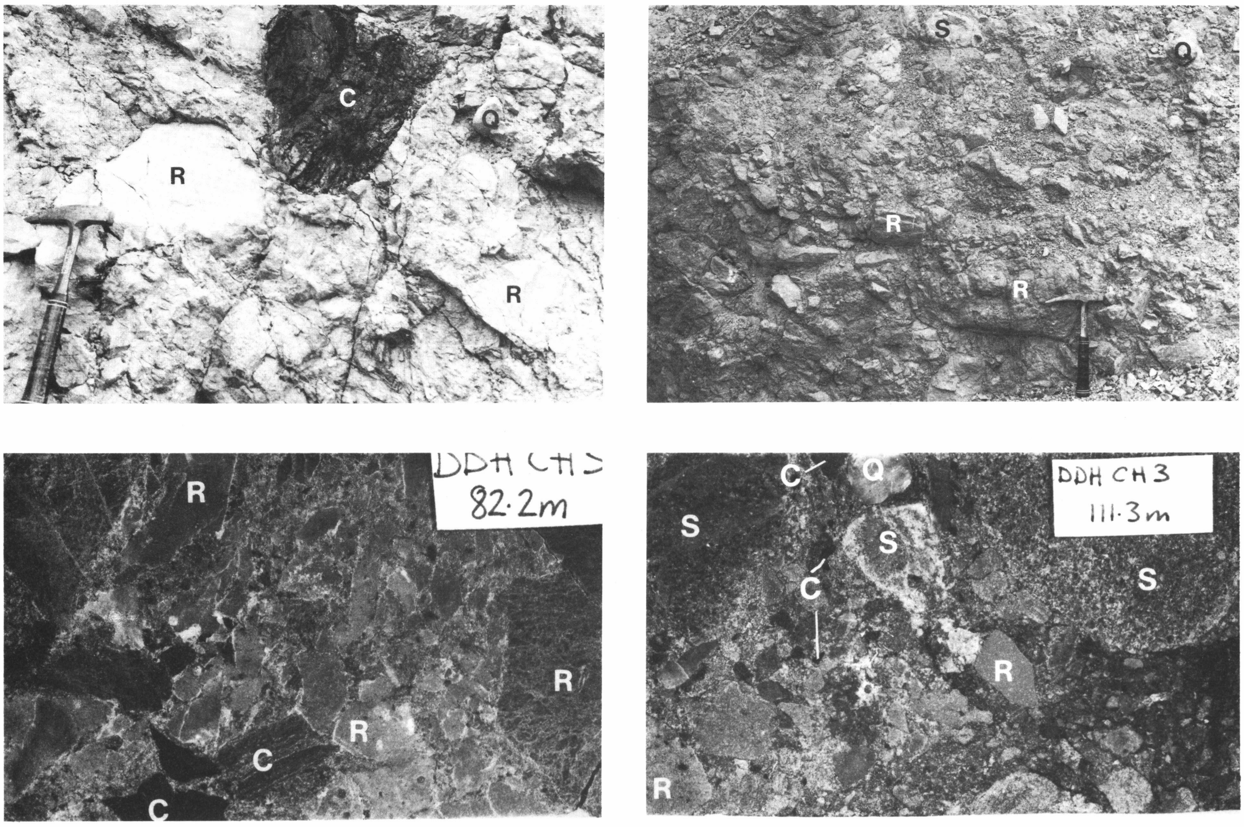


Figure 7. (Upper 2 photographs) Clasts of rhyolite (R), quartzite (Q), sandstone (S), and carbonaceous schist (C) in the polymictic debris-flow conglomerate. West wall of pit adit. (Lower 2 photographs) Polymictic debris-flow conglomerate from diamond-drill hole CH3, core 5 cm wide.

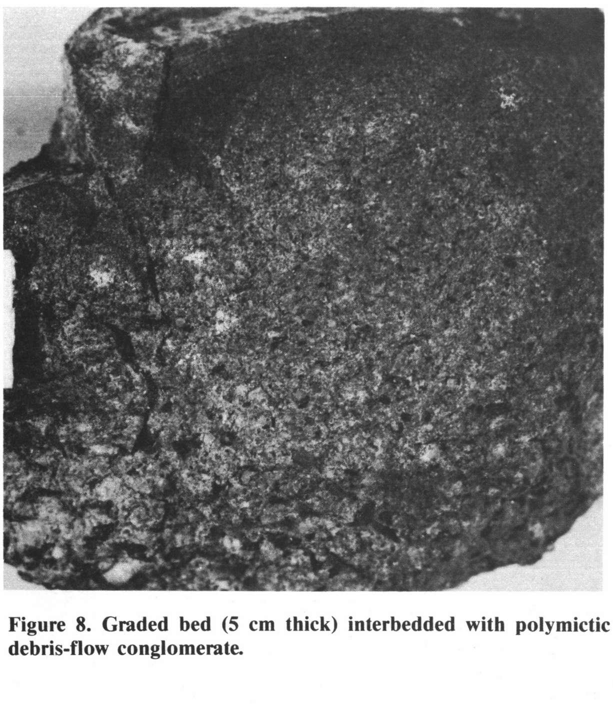


Figure 8. Graded bed (5 cm thick) interbedded with polymictic debris-flow conglomerate.

graded beds indicate the presence of at least three flows in the roughly 20 m thick sequence exposed in the mine workings. The association with sub-aerial felsic volcanics and related valley-fill volcanolithic sediments indicates a fluvial, high-energy environment of deposition.

Owing to the mixture of rounded, sub-rounded, and sub-angular clasts with angular clasts, the term 'conglomerate' is preferred over 'breccia', which may be readily confused with the earlier interpreted origin of the rock as a cognate volcanic breccia. The recommended name is 'debris-flow conglomerate'.

Geology of the Coronation Hill open cut

Our mapping of the open cut (Fig. 9) has revealed 2 previously unrecorded major structures and determined the outcrop area of the debris-flow conglomerate. The new structures are an east-southeast subvertical fault, which throws the conglomerate against volcanics on the south side, and a shear zone trending east-northeast across conglomerate and volcanics with no apparent offset.

Only the walls of the pit contain outcrop, as the floor is entirely covered by rubble. The pit consists of an open adit about 10 m wide by 65 m long driven horizontally southwards into a rising hillside with an original gradient of about 1 in 3, to a 33 × 24 m hole that originally was connected to underground workings by underground stopes. The hole is now about 10 m deep and much of the eastern part is concealed by a scree slope. Therefore, all observations were restricted to wall areas. Geology of the pit floor is adapted from an unpublished plan by United Uranium N.L. dated 1969 with geology by D. Zimmerman. Our mapping was controlled by tape and compass.

The conglomerate extends along three-quarters of the western wall of the pit and entrance, and is truncated by subvertical faults against purple, green and grey, commonly sheared volcanics in the west corner of the pit and along the eastern wall. Graded beds in the conglomerate indicate dips of 42° to 90° to the west.

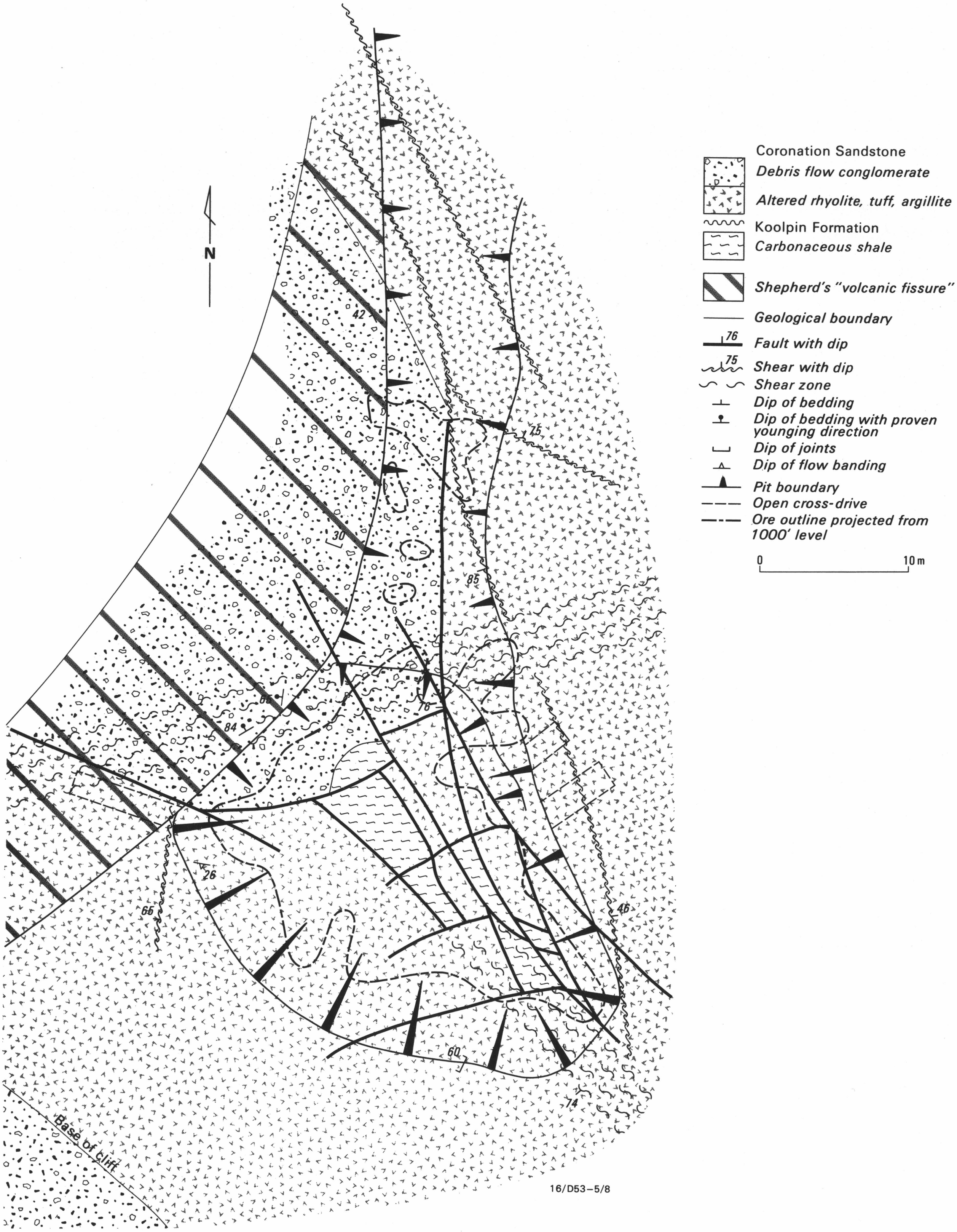


Figure 9. Geology of Coronation Hill mine pit, showing outline of ore and Shepherd's (1967) 'volcanic fissure'.

The volcanics are massive, fine, and extensively sheared, jointed, and stained. Their original lithology is obscure, but may have been interbedded rhyolite, argillite, and tuff, by analogy with rock types mapped on the surface east of the pit by J. Harrison (unpublished data, United Uranium N.L., 1970) and described below surface by Allen (1954) and G. Pietsch (unpublished data, Noranda Australia Ltd, 1977). They are now mainly schistose chloritic rocks, comprising about 75 per cent quartz, 20 per cent chlorite and 5 per cent iron oxides. Locally, cherty siltstone bands may represent bedding. The rock is extensively sheared and jointed, but in places a fine arenaceous texture is preserved. Fine brecciation is common, and in places the rock is laced with fine quartz veinlets. Strong hematite staining and, in places, massive hematite replacement accompanies some major fractures, and a zone of strong bleaching up to 7 m wide accompanies the east-northeast shear zone where it cuts the volcanics.

Unpublished plans of United Uranium N.L. dated December 1970 (geologist J. Harrison) show a carbonaceous shale lens within volcanics in the south wall of the pit, which we were unable to verify. Alternatively, it is highly chloritic schist derived by alteration of the volcanics, or it may be a faulted wedge of carbonaceous shale from a deeper stratigraphic level, which has been subsequently concealed by scree.

An interpretative cross-section based on our mapping, geological logs of drillholes BMR1 and BMR2 by Allen (1953), and our own logging of Noranda's drillhole CH3, is shown in Figure 10. We interpret the open cut area as a prism of Coronation Sandstone conglomerate, originally continuous with sandstone and conglomerate forming the cliffs above the pit, and now downfaulted into stratigraphically lower felsic volcanics of the same formation. Narrow fault wedges of carbonaceous shale lie within the prism of conglomerate and at depth may be isolated from their Koolpin Formation source.

Uranium-gold mineralisation was concentrated in carbonaceous clast-rich portions of the prism around and above the shale wedges, but extended into the shale wedge in places, and elsewhere as oxidised ore, into the felsic volcanics. The largest uranium ore shoot was in a steeply plunging triangular zone of intense faulting south of the east-northeast shear zone (Fig. 9). Gold mineralisation formed both veinlets, which cut the pitchblende ore, and disseminations. Gold also formed separate ore shoots in places, so it appears that the controls to uranium and gold mineralisation were unrelated. Shepherd's (1967) 'volcanic fissure' lay west of this triangular zone and was portrayed as a northeast-trending 20 m × 100 m body impinging on the west wall of the pit and continuing southwest to the main escarpment of Coronation Hill.

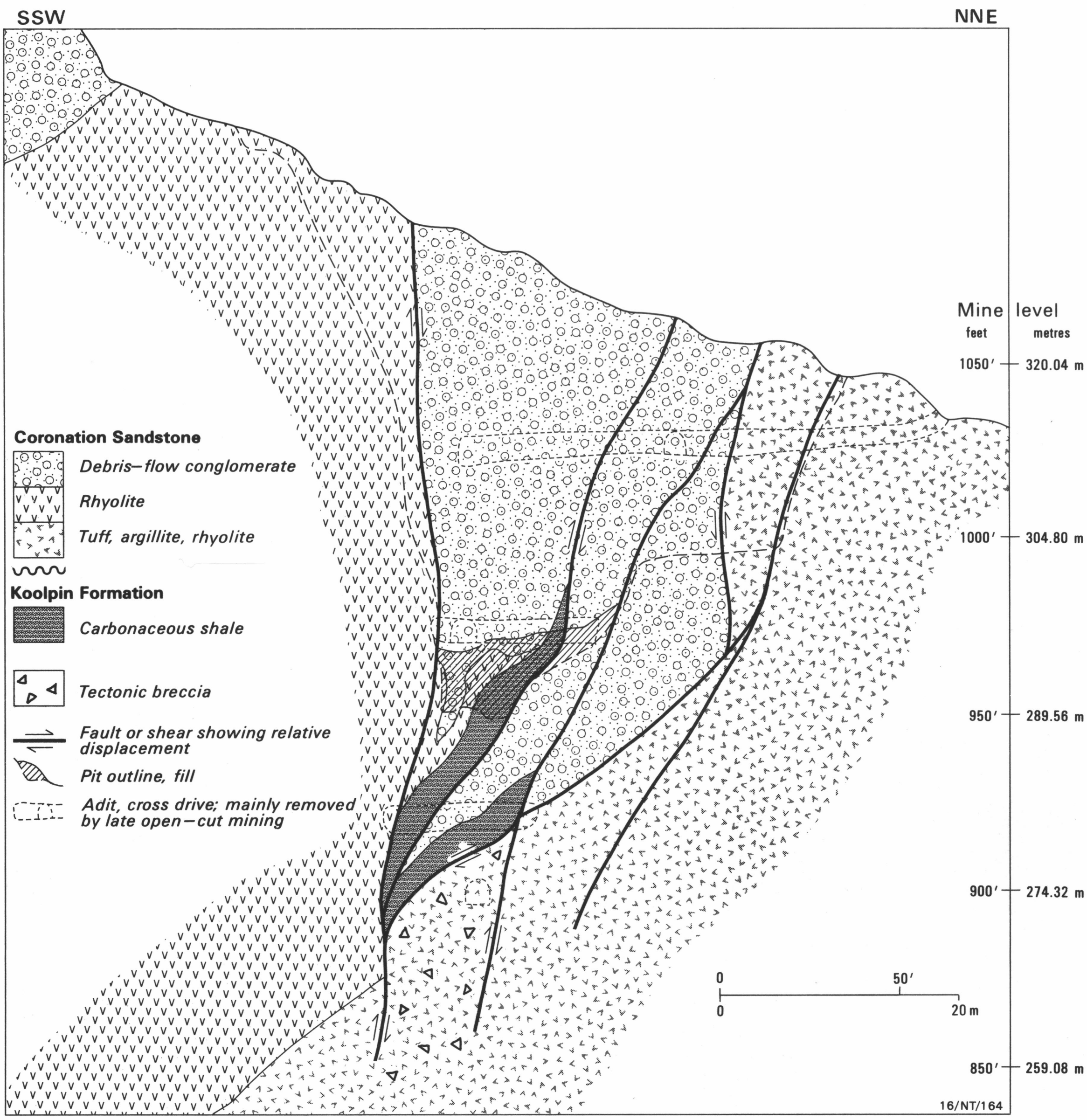


Figure 10. Interpretative cross-section of the Coronation Hill U-Au mine, based on drillhole logs of Allen (1954), our log of the 1976 Noranda drillhole, and recent mapping.

Relation to other U-Au deposits of the district

The other deposits of the district (El Sherana, El Sherana West, Rockhole, Palette, Saddle Ridge, Scinto V, Scinto VI, Koolpin Creek, Skull, and Sleisbeck) all lie on or close to the major northwest-trending faults or related conjugate faults within 400 m of a major fault (Needham, 1985). Primary mineralisation is hosted by carbonaceous and ferruginous shale of the Koolpin Formation, which is commonly in faulted contact with sandstone or volcanics of the Coronation Sandstone. The sandstone and volcanics commonly host secondary uranium minerals, reflecting the oxidising environment. The U-enriched Pul Pul Rhyolite and rhyolite of the Coronation Sandstone are the probable metal source (Ayres & Eadington, 1975), and the common juxtaposition of Koolpin Formation and sandstone of the Coronation Sandstone strongly suggests that the sandstone provided a conduit for mineralising fluids from the volcanics to the carbonaceous shale.

Misidentification of the host rocks of the Coronation Hill deposit as a volcanic vent has made this deposit difficult to fit into models advanced for the genesis of the other deposits of the district, which were reviewed by Crick & others (1980). Our interpretation makes the host rocks at Coronation Hill essentially the same as those in the other deposits, so that the same genetic model may apply to all the U-Au deposits of the area.

At Coronation Hill, volcanics (uranium source rocks) and sandstone (conduit bodies) of Coronation Sandstone are in faulted contact with Koolpin Formation carbonaceous and ferruginous shales (reductant rocks), in an area crossed by both northwest-trending faults and conjugate faults. In this case, precipitation of uranium took place partly in the conduit body, as large clasts of carbonaceous shale within the debris-flow conglomerate provided a sufficiently reduced environment.

Conclusions, uranium ore genesis model

The host rock at the Coronation Hill U-Au mine is a debris-flow conglomerate, developed in a high-energy fluvial environment during deposition of the Coronation Sandstone of the El Sherana Group. The landscape was rugged, consisting of ridges of shale and valley infills of sandstone, pyroclastics, and felsic volcanics. High-energy fluvial surges reworked the sandstone (clastic dykes, sandstone clasts of the Coronation Sandstone), ripped up and transported boulders of shale (Koolpin Formation), volcanics and volcaniclastics (Coronation Sandstone volcanic valley-fill), and reworked older mature pebbly arenites (the pre-Koolpin Formation Mundogie Sandstone). These clasts were dumped in a matrix of quartz-rich angular grains derived mainly from the valley-fill volcanics.

Several debris flows were interspersed with normal fluvial transport of sand and silt, and graded beds developed as currents waned. The landscape rapidly matured, so that the debris flows were overlain by relatively mature pebbly sands. Later, faulting juxtaposed the Coronation Sandstone sequence with Koolpin Formation, and groundwater circulation was induced by tectonic disturbance of groundwater gradients. The age of faulting is demonstrated as post 1650 Ma, as the same faults displace Middle Proterozoic sandstone of this age in the same district (Page & others, 1980). Thus, mineralisation took place by movement of low-temperature fluids from the U-enriched volcanics into the conduit sandstone and eventually into the reduced debris-flow conglomerate and carbonaceous shale.

All the uranium deposits of the South Alligator Valley district are epigenetic and have similar origins. However, on the basis of the minor component of in-situ carbonaceous and ferruginous shale (the major host of all the other deposits), the Coronation Hill deposit can be classified as 'epigenetic sandstone type', reflecting the coarse clastic nature of the host rock.

An aspect of the Coronation Hill deposit, and the other uranium deposits of the district that carried gold, is the apparent lack of relation between the extensive chlorite/hematite alteration associated with all these deposits and the gold mineralisation. As both gold veins and 'dark chlorite + quartz' are late events, they could possibly be genetically related.

The very finely disseminated nature of gold in the recently discovered deposit east of the old workings may indicate an early, possibly deuteric, mineralisation, distinct from the obviously late remobilised gold veins that cut uraninite ore in the U-Au orebody. Two distinct mineralising episodes are indicated with common or similar localising mechanisms. Thus, those other gold-bearing uranium deposits of the region indicate likely sites of low-grade gold-PGE mineralisation in nearby altered felsic volcanics.

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