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Petrographic Descriptions for Multiple Thin Sections from Sixteen Rock Samples (Mount Gee Epithermal System), and One from the Parabarana Area (Mount Painter Inlier), South Australia

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SIGNED	
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Petrographic Descriptions for Multiple Thin Sections from Sixteen Rock Samples (Mount Gee Epithermal System), and One from the Parabarana Area (Mount Painter Inlier), South Australia

SUMMARY

1. Rock Samples

- A collection of 16 rock samples with 32 polished thin sections from the Mount Gee Epithermal System (Arkaroola area, South Australia), and 1 sample with 3 sections from the Parabarana area (Mt Painter Inlier), have been studied using optical petrographic and mineragraphic methods.

2. Brief Results

- A summary of rock names and mineralogy is provided in TABLE 1.

- *Mount Gee Epithermal System, Arkaroola area*

  – **Banded epithermal rocks** formed as open-space deposits by crystallisation from silica-Fe-P-REE-S-bearing hydrothermal fluids at low P-T conditions. They are composed of colloform banded assemblages mainly of quartz, accompanied by lesser hematite and monazite, and local trace sulfides (pyrite, chalcopyrite) and magnetite. No carbonaceous or uraniferous minerals have been identified, but their possible very fine grain size, metamictisation, and acceptance of poor polish renders such minerals difficult to identify optically; other specialist services might be required. Quartz displays a wide range of textures typical of epithermal environments, including fine-grained massive microcrystalline quartz, subradiating bladed quartz with tiny fluid inclusions, coarse-grained subradiating quartz with or without fluid inclusions, subradiating crustiform quartz projecting into vughs, massive medium-grained granular quartz, thinly colloform chalcedonic quartz, and gel-like quartz composed of tiny ovoids in microcrystalline matrix. In many samples, occurrence of the minerals and their overgrowing textures allows identification of a mineral paragenetic sequence (see TABLE 1). Commonly, hematite + monazite ± sulfides formed as an early fine-grained assemblage (grey in hand sample). Some hematite blades may contain magnetite as relict kernels, indicating early-crystallised magnetite was followed by hematite with increasing oxidation of the fluid. Different textural forms of hematite are observed in different assemblages: bladed specular hematite is relatively early, whereas later hematite may form as very fine-grained (submicron-sized) specks concentrated in thin growth zones in quartz (red or yellow bands) or as tiny acicular crystals (black bands). Monazite occurs as small subhedral to euhedral crystals in close proximity to hematite crystals.
  Hydrothermal breccia (2065337, 2065338) is composed of early-formed epithermal quartz-hematite-monazite fragments enclosed by a quartz-clay cement without mineralisation.

  – **Clastic rocks** are identified in many samples and are considered to have formed by sedimentation which produced poorly sorted to sorted clastic sediments of diamictite, sandstone and pebbly siltstone rock types.
  Diamictite is characterised by minor but relatively large subangular to subrounded lithic clasts several millimetres to ~2 cm in size, in finer-grained sandy to silty matrix. The lithic clasts include:
    i) sericite-hematite altered felsic crystalline rocks of possible middle greenschist facies meta-sedimentary origin composed of quartz, K-feldspar (microcline), muscovite, biotite, hematite (with relict magnetite), zircon;
    ii) other meta-sedimentary rocks of meta-sandstone and meta-siltstone types with preserved clastic textures;
    iii) non-metamorphosed but sericite-hematite-monazite altered felsic granitoid with micrographic texture composed of quartz, K-feldspar (orthoclase weakly inverted to microcline), sericite, hematite, monazite, zircon;
    iv) sericite-hematite altered acid volcanic fragments containing phenocrysts of K-feldspar and quartz in sericite-altered devitrified groundmass.
  The matrix is composed of abundant subangular to subrounded sand-sized crystal fragments (quartz >> K-feldspar mainly microcline >> muscovite > hematite (includes trace magnetite) >

rutile) and tiny quartz clasts in a sericite mat. Particular interpretations include: clastic components were derived from diverse meta-sedimentary, felsic granitoid and felsic volcanic sources; many of those rocks had suffered alteration prior to deposition; the subrounded shapes of many of the clastic quartz grains suggest they experienced a significant amount of subaerial transport prior to deposition; fine-grained non-foliated sericite in matrix is inferred to have formed by recrystallisation of primary clays at moderately low temperature, and provides the competency of the rock; complexities in interpretation of iron oxides are introduced by inferred hematite-sericite alteration of rocks prior to deposition, possible weak formation of Fe-oxide as submicron hematite during low-temperature recrystallisation, and subsequent near-surface meteoric effects.

Sandstone (2065350, 2065351) formed as a well-sorted, clast-supported sediment composed of abundant crystal fragments (K-feldspar > quartz > muscovite >> hematite) in minor fine-grained clay matrix. The dominance of microcline K-feldspar in the clastic assemblage is notable, indicating that the sediment is feldspathic and was sourced from microcline-bearing rocks. Low-grade recrystallisation of the clay formed new non-foliated sericite and caused suturing of grain margins, producing the observed competent rock. The presence of clastic hematite is consistent with pre-depositional hematite alteration observed in lithics of the diamictite.

Pebbly siltstone (2065351) contains minor relatively large subrounded lithic fragments (compare diamictite; felsic metamorphic rock composed of quartz, microcline, muscovite, and hematite after magnetite) in fine-grained silty matrix of crystal clasts (muscovite > K-feldspar (microcline) > quartz) and fine-grained sericite. The high abundance of clastic muscovite flakes aligned in the bedding plane supports aqueous deposition.

– **Granitoid** (2065339, 2065347) is interpreted to have crystallised as a massive, medium-grained felsic igneous rock composed of quartz + K-feldspar + ?plagioclase + minor others (ilmenite, zircon, ?monazite). Primary minerals and textures have been partly obscured by alteration effects, producing albite after primary plagioclase, microcline after primary K-feldspar, sericite/muscovite, rutile, hematite, and likely trace monazite. Alteration of potassic type may have affected 2065347 (K-feldspar + muscovite + magnetite + rutile). Despite the alteration effects, the protoliths of these rocks are inferred to have been a K-feldspar-rich granitoid (eg ?monzogranite or ?syenogranite). Late fracturing of 2065347 produced fractures and micro-brecciation zones sealed by hematite.

- *Parabarana area, Mt Painter Inlier*

– **Altered meta-?sediment** has suffered strong replacement by alteration epidote + actinolite + plagioclase + minor titanite + calcite + magnetite. All primary minerals and textures have been destroyed, but indistinct mineralogical lamination is considered to reflect primary layering. The mineral assemblage suggests that alteration by low-CO_2 aqueous fluid affected the rock in a static environment (no foliation) at P-T conditions of the greenschist facies.

– **Altered coarse-grained crystalline rock (granitoid)** suffered selective pervasive replacement by plagioclase + actinolite + epidote + titanite, most likely by the same fluid which modified the meta-?sediment. Partial preservation of some igneous minerals (K-feldspar, ilmenite, zircon) and textures suggests that the protolith crystallised as a medium-grained K-rich granitoid, possibly of monzonitic or syenitic composition. The absence of quartz is notable; it remains uncertain whether this is a primary feature, because it is possible quartz was destroyed during alteration in response to undersaturation of the hydrothermal fluid in silica. The intensity of alteration of the granitoid and the meta-?sedimentary host rock has obscured the primary relationship between the two rock types, but it is considered likely that the granitoid intruded the meta-sediment.

TABLE 1: SUMMARY OF ROCK NAMES AND MINERALOGY

SAMPLE	ROCK NAME	MINERALOGY*			
		Primary**	Metamorphic/ Alteration	Open space deposits / Veins / Fracture seals***	Weath-ering
Mount Gee, Arkaroola area					
2065334-A	Colloform banded quartz-hematite-monazite epithermal rock	-	-	Qtz, hem, mon, mt; Qtz, hem; Qtz	-
2065334-B	Colloform banded quartz-hematite-monazite rock	-	-	Qtz, hem, mon; Qtz; Qtz, hem; Qtz	-
2065336	Goethite-clay (weathered) rock	-	-	-	Goe, cla
2065337	Weakly weathered, siliceous hydrothermal breccia	-	-	Qtz, hem, mon; Qtz, cla(?kao)	Goe/hem, cla
2065338	Weakly weathered, siliceous hydrothermal breccia		-	Qtz, hem, mon; Qtz, cla	Hem
2065339	Altered granitoid	Kf, qtz, ilm, zir, mon?	Alb, ser, rut, mon?	Qtz	-
	Banded quartz-hematite-monazite epithermal rock	-	-	Qtz, hem, mon	-
2065340	Quartz-hematite-monazite epithermal rock	-	-	Qtz, hem, mon; Qtz	-
2065341	Quartz-hematite-monazite epithermal rock	-	-	Qtz, hem, mon, py, cpy; Qtz, hem, mon	-
2065342	Quartz-hematite-monazite epithermal deposit	-	-	Qtz, hem, mon; Qtz, hem, mon	-
2065343-A	Quartz-hematite-monazite epithermal rock	-	-	Qtz; Qtz, hem, mon; Hem, ser	-
2065343-B	Quartz-hematite-monazite epithermal rock	-	-	Qtz; Qtz, hem, mon, py; Qtz	-
2065345	Quartz-hematite-monazite epithermal rock	-	-	Qtz, hem, mon; Qtz	-
2065346	Partly weathered, quartz-hematite-monazite epithermal rock	-	-	Qtz, hem, mon; Qtz	Hem, goe
2065347	Fractured and hematite altered, K-feldspar-muscovite-?magnetite altered granitoid	Qtz, Kf?, mon?	Kf, mus, mt, mon?, rut, hem	Hem	-
2065348	Sericite-hematite diamictite	Qtz, lith, Kf, hem, mus, tou, zir	Ser, hem	-	-
2065349	Sericite-hematite diamictite	Qtz, lith, hem, Kf, rut, mt, mus, zir	Ser, hem	-	-
2065350	Sericite-hematite feldspathic sandstone	Kf, qtz, mus, hem	Ser, hem	Qtz, ser, hem	-
2065351	Layered sediments:				
	Sandstone	Kf, qtz, mus	Ser, hem	-	-
	Pebbly siltstone	Mus, lith, Kf, qtz	Ser, hem	-	Hem

cont…

TABLE 1: SUMMARY OF ROCK NAMES AND MINERALOGY (cont.)

SAMPLE	ROCK NAME	MINERALOGY*			
		Primary**	Metamorphic/ Alteration	Open space deposits / Veins / Fracture seals***	Weath- ering
Mount Gee, Arkaroola area (cont.)					
2065352	Layered sediments:				
	Granule breccia	Lith, Kf, qtz, mus	Ser	-	-
	Siltstone	Kf, mus, qtz	Ser	-	Goe, hem
2065353	Colloform banded quartz-hematite epithermal rock	-	-	Unk; Qtz; Qtz, hem; Qtz	Cla
2065354-A	Weakly weathered sericite-hematite diamictite	Qtz, lith, Kf, mus, zir	Ser, hem	-	Goe
2065354-B	Weakly weathered sericite diamictite	Qtz, lith, Kf, mus	Ser	-	Goe
2065356	Weakly weathered, sericite diamictite	Qtz, lith, Kf, mus	Ser	-	-
2065357	Sericite diamictite	Qtz, lith, Kf, mus, tou	Ser	-	Goe
2065358-A	Hematite stained (oxidised) sericite diamictite	Qtz, Kf, lith, mus, hem	Ser	-	Hem
2065358-B	Hematite stained (oxidised) sericite diamictite	Qtz, lith, Kf, mus, hem/mt	Ser	-	Hem
2065360-A	Hematite stained (oxidised) pebbly sericite diamictite	Qtz, lith, Kf, mus, rut, bio, zir	Ser	Qtz, car(cal)	Hem
2065360-B	Partly oxidised, pebbly sericite diamictite	Qtz, lith, Kf, mus, zir	Ser	-	Hem
2065362-A	Partly oxidised, colloform banded quartz-hematite epithermal rock	-	-	Qtz, hem; Qtz; Qtz	Goe
2065362-B	Partly oxidised, colloform banded quartz-hematite epithermal rock	-	-	Qtz; Qtz; Qtz, hem; Qtz	Goe
2065364	Weakly oxidised, weakly laminated quartz-hematite epithermal rock	-	-	Qtz, hem; Qtz	Goe, ?jar
2065365	Weakly oxidised, quartz-?sulfide epithermal rock	-	-	Qtz, opq(?py); Qtz, opq(?py)	Goe
Parabarana area, Mt Painter Inlier					
2065335-A	High-intensity epidote-actinolite-plagioclase altered meta-laminated rock (meta-?sediment)	-	Epi, act, pla, car(cal), tit, mt	-	-
2065335-B	Altered intrusive rock and wall rock:				
	Actinolite-zoisite altered granitoid (?monzonite)	Kf, ilm, zir	Pla, act, epi, tit	-	-
	High-intensity epidote-actinolite-plagioclase altered meta-?sediment	-	Epi, act, pla, tit, car(cal)	-	-

cont…

TABLE 1: SUMMARY OF ROCK NAMES AND MINERALOGY (cont.)

SAMPLE	ROCK NAME	MINERALOGY*			
		Primary**	Metamorphic/ Alteration	Open space deposits / Veins / Fracture seals***	Weath-ering
Parabarana area, Mt Painter Inlier (cont.)					
2065335-C	Actinolite-epidote altered granitoid (?monzonite)	Kf, ilm, zir	Pla, act, epi, tit, mt	-	-

NOTES

*: Minerals are listed in each paragenesis according to approximate decreasing abundance.

**: Only primary minerals currently present in the rock are listed. Others may have been present, but are altered.

***: Earlier parageneses are separated from later parageneses by a semicolon.

Mineral abbreviations

Act = actinolite; alb = albite; bio = biotite; cal = calcite; car = carbonate minerals; cla = clay minerals; epi = epidote; goe = goethite; hem = hematite; ilm = ilmenite; kao = kaolinitic clay; Kf = K-feldspar (variably microcline, orthoclase); lith = lithic fragments; mon = monazite; mt = magnetite; mus = muscovite (coarser-grained white mica); opq = opaque minerals; pla = plagioclase; py = pyrite; qtz = quartz; rut = rutile; ser = sericite (finer-grained white mica); tit = titanite; tou = tourmaline; unk = unknown; zir = zircon; ?min = uncertain mineral identification; min? = uncertain mineral paragenesis.

1 INTRODUCTION

A collection of thin sections and their remnant rock offcuts and samples was provided by Mr Stephen Hore (Geological Survey of South Australia, Adelaide, SA) on 28 April 2015.

Background notes and a sample list were provided by the client. Most of the samples originate from the Mount Gee epithermal system, near Arkaroola in the Flinders Ranges, South Australia. For some samples, multiple sections (A, B, C) are provided. One sample (sample 2065335, sections A, B and C) originates from a different area, namely the Parabarana area of the Mt Painter Inlier.

Some notes were provided by the client regarding the geological environment:

> 'Fe-rich and siliceous fluids of pre- and syn-epithermal system intruding brecciated granites which may have also been K-metasomatised.
>
> Abbreviated sequence of events possibly encountered (oldest to youngest … but maybe some variability:
> • brecciation of granite
> • intrusion of Fe-rich fluids
> • intrusion of uraniferous Fe-rich fluids
> • intrusion of Fe and siliceous fluids
> • intrusion/deposition of diamictite (if not hydrothermal then maybe preferred option of glacial and/or fluvial origin); metamorphic grade of clasts (and type) and matrix is of significant interest
> • winnowing/deposition of Fe-0rich sediments into brecciated granite or voids (timing unsure)
> • intrusion of siliceous fluids (epithermal system proper) (Mount Gee Sinter)
> • any evidence of organic matter, uranium minerals'

Particular requests were:

i) Provide a combined petrographic and mineragraphic description for each polished thin section.

ii) Note any relationships between multiple slides from the same sample.

iii) In the Mount Gee samples, comment on the nature of the diamictite samples, including metamorphic grade of the clasts and the nature of the matrix.

iv) In the Parabarana sample, comment on the intrusive relationship in sample 2065335.

Excerpts from this report were provided by email to Mr Hore on 27 May 2015. This report contains the full results of this work.

2 METHODS

At Mason Geoscience Pty Ltd conventional transmitted and reflected polarised light microscopy was used to prepare the combined petrographic descriptions. It is notable that the degree of polish is imperfect, such that much of the hematite displays a relatively poor polish in which small ragged unpolished pits are distributed through better-polished areas. Modal mineral abundances are optical estimates, and are considered to have approximate absolute errors as follows: ±~5 vol.% at an abundance of 20 vol.%, ±~3 vol.% at 10 vol.%, and ±~2 vol.% at 5 vol.%. Paragenetic stages of development of each rock are indicated in the mineral modal list, where each mineral is assigned to a numerical paragenesis (paragenesis 1 is earliest; paragenesis 2 overprints 1; paragenesis 3 overprints both 2 and 1; etc). Progressively younger stages within epithermal mineral deposition are indicated by letters: eg Epithermal 1a, 1b, 1c). **The paragenetic stages display relative timing insofar as they can be determined within each sample**, and are not meant to be directly equated between samples although this may be correct for some samples.

The term ‘diamictite’ is used in this report according to the following definition: ‘A comprehensive, nongenetic term proposed by Flint et al. (1960) for a nonsorted or poorly sorted, noncalcareous, terrigenous sedimentary rock that contains a wide range of particle sizes, such as a rock with sand and/or larger particles in a muddy matrix; eg a tillite or a pebbly mudstone’. Glossary of Geology. 2nd edition. RL Bates & JA Jackson (eds): American Geological Institute, 1980.

3 PETROGRAPHIC AND MINERAGRAPHIC DESCRIPTIONS

The combined petrographic and mineragraphic descriptions are provided in the following pages.

SAMPLE ID : 2065334-A (Mt Gee Epithermal System, Arkaroola, SA)

STRATIGRAPHY : Mount Gee Sinter

LITHOLOGY : -

SECTION NO. : 2065334-A

HAND SPECIMEN : The rock sample is composed of millimetre- to centimetre-thick bands that are variably translucent grey, white, red and lustrous metallic black. Colloform banding is evident in parts of the rock.

ROCK NAME : Colloform banded quartz-hematite-monazite epithermal rock

PETROGRAPHY AND MINERAGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	**Vol %**	**Origin**
Quartz (subradiating, coarse-grained)	25	Epithermal 1a
Hematite (specular, coarse-grained)	5	Epithermal 1a
Monazite	Tr	Epithermal 1a
Magnetite	Tr	Relict epithermal 1a (inclusions in hematite)
Quartz (colloform, chalcedonic)	49	Epithermal 1b
Hematite (cryptocrystalline)	5	Epithermal 1b
Quartz (massive, granular, coarse-grained)	15	Epithermal 1c

In polished thin section, this sample displays an inequigranular colloform space-filling texture.

Quartz dominates the rock, and different textural types are distinguished:

i) Coarse-grained quartz with feathered subradiating texture is moderately abundant, and appears to have formed early in the banded sequence. It is translucent to white in the hand sample. Small fluid inclusions with ragged shapes, possibly of single-phase aqueous type, are concentrated in diffuse zones subparallel to the blading of the subradiating quartz, and are responsible for a white colour in hand sample in indistinct zones.

ii) Coarse-grained massive granular quartz is moderately abundant. It is translucent to white in the hand sample. It forms equant anhedral grains that form a massive granular mosaic. This quartz occurs in bands which overgrow the earlier subradiating quartz, and also fills late vughs where it has overgrown colloform chalcedonic quartz. Much of this quartz lacks fluid inclusions, and is translucent in hand sample. Small ragged fluid inclusions are concentrated in growth zones in some of the later coarse-grained quartz, and these are responsible for its white appearance in hand sample.

iii) Chalcedonic quartz is abundant. It displays a pale yellow colour and is concentrated in thin and thicker colloform bands which overgrow coarse-grained quartz. The chalcedonic quartz displays its typical fine-grained thinly bladed subradiating texture, where the blades have grown discordant to the colloform banding. This chalcedonic quartz is red in hand sample, because of the presence of submicroscopic (cryptocrystalline) red hematite that is dispersed through the colloform quartz and is more densely concentrated in thin colloform laminae between the chalcedonic quartz layers.

Hematite occurs in two forms:

i) Coarser-grained bladed hematite crystals ~0.5 mm long are concentrated in a dense layer, developed within the early coarse-grained subradiating quartz. Some hematite also occurs as smaller, finer-grained ragged patches intimately intergrown with the subradiating quartz. A trace amount of magnetite occurs within the coarser-grained bladed hematite as small ragged kernels, apparently representing early-formed magnetite now mostly replaced by the bladed hematite crystals.

ii) A minor amount of hematite occurs as cryptocrystalline specks and small aggregates that are sprinkled through the chalcedonic quartz and also are concentrated in thin colloform laminae between the colloform chalcedonic quartz bands.

Monazite is present in trace amount. It forms small but well-shaped small equant crystals ~0.2-0.4 mm in size, closely associated with small fine-grained hematite aggregates within the early bladed coarse-grained quartz. No monazite is observed within the distinct hematite-rich band within the coarser-grained subradiating quartz, and no monazite is observed in the later-formed bands of the rock.

INTERPRETATION :

This sample is considered to represent an open space-filling deposit of hydrothermal origin, more specifically in a near-surface epithermal environment. It crystallised from different hydrothermal fluids which infiltrated the environment from time to time. Progressive stages of mineral deposition are inferred from overgrowth textures, particularly convex-outward growth of colloform bands:

1. Early quartz + hematite/magnetite + monazite

Early-formed quartz was relatively coarse-grained and displays feathery subradiating textures. Hematite formed bladed crystals concentrated in a millimetre-wide lamina within the early band, and finer-grained hematite formed small aggregates within the quartz. Trace magnetite is preserved as small ragged kernels in some of the hematite crystals, suggesting early-formed magnetite was rapidly replaced and overgrown by hematite. Monazite formed small crystals associated with fine-grained hematite dispersed through the coarse-grained subradiating quartz.

2. Quartz

Massive granular quartz formed as a band overgrowing the earliest quartz + hematite/magnetite + monazite band.

3. Chalcedonic quartz + hematite

Thinly colloform quartz and hematite developed as overgrowths on the earlier mineral bands. The hematite tends to be concentrated in thin colloform laminae, but also is sparsely sprinkled through the chalcedonic quartz bands. The fine-grained texture of these colloform bands suggests that it formed by rapid cooling of a particular siliceous-ferruginous fluid batch. The presence of hematite is responsible for the bright red colour of this material in the hand sample.

4. Latest quartz

Latest massive granular quartz fills vughs in the colloform chalcedonic quartz + hematite. No remnant open space is observed.

SAMPLE ID : 2065334-B (Mt Gee Epithermal System, Arkaroola, SA)

STRATIGRAPHY : Mount Gee Sinter

LITHOLOGY : -

SECTION NO. : 2065334-B

HAND SPECIMEN : The rock sample displays intricate banding of colloform type, where early massive grey patches are overgrown by translucent to white quartz, which in turn is overgrown by thinly colloform red laminae (hematite-bearing). Minor small vughs are present.

ROCK NAME : Colloform banded quartz-hematite-monazite rock

PETROGRAPHY AND MINERAGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	Vol %	Origin
Quartz (subradiating, medium-grained)	20	Epithermal 1a
Hematite (bladed, fine-grained)	3	Epithermal 1a
Monazite	Tr	Epithermal 1a
Quartz (granular, medium-grained, crustiform)	36	Epithermal 1b
Quartz (chalcedonic, colloform)	20	Epithermal 1c
Hematite (cryptocrystalline)	1	Epithermal 1c
Quartz (granular, medium-grained)	20	Epithermal 1d

In polished thin section, this sample displays a colloform space-filling texture, with mineral parageneses indicated by overgrowth textures.

Quartz dominates the rock, and different textural types are identified:

i) A significant amount of quartz occurs as small subradiating grains ~0.2-0.4 mm long. These are concentrated in a large patch at one end of the sample (grey in hand sample). Minute fluid inclusions with sinuous irregular shape are concentrated in grey clouds in this quartz, and in places appear to weakly define growth zones in the quartz grains. These fluid inclusions are too small for better optical characterisation.

ii) Much massive granular quartz forms equant anhedral grains mostly ~0.4-1.5 mm in size. This quartz has overgrown the finer-grained quartz of i) above. Euhedral crystal faces (crustiform texture) is developed where these quartz crystals are overgrown by later minerals (see chalcedonic quartz next).

iii) Chalcedonic quartz occurs in moderate amount as fine-grained fibrous thin colloform laminae ~0.2-0.5 mm thick, which have overgrown the freely growing euhedral quartz crystals of ii) above. The quartz fibres display the typical cross-lamination orientation.

iv) Massive granular quartz, identical to the quartz of ii) above, overgrows the thin colloform chalcedonic quartz bands and completely fills vughs.

Hematite occurs in minor amount, and two textural types are observed:

i) Some hematite occurs in minor amount as tiny bladed crystals (specularite) ~10-100 μm in size, which are concentrated in small ragged aggregates and trails within the early-formed finer-grained subradiating quartz mosaic. This hematite contributes the dull grey colour to this part of the rock.

ii) Some hematite occurs in trace amount as cryptocrystalline red spots and small aggregates which are located within the colloform chalcedonic quartz laminae. This hematite is sparsely sprinkled through the chalcedonic quartz, but also is concentrated along thin laminae within the thinly laminated chalcedonic quartz bands.

Monazite is uncommon. It forms tiny equant subhedral crystals ~30-50 μm in size, displaying the typical high relief, lack of colour, moderate birefringence, and inclined extinction to cleavages. They occur only in close association with the fine-grained specularite hematite, and therefore occur only in the grey part of the rock observed in the hand sample.

INTERPRETATION :

This sample crystallised in open space in an epithermal environment, possibly as a siliceous sinter deposit. This produced a colloform banded deposit composed of quartz + minor hematite + trace monazite. Textures allow identification of progressive stages (parageneses) of mineral deposition:

1. Earliest quartz + minor hematite + trace monazite

The earliest quartz is fine-grained and subradiating in habit, and is interspersed with very fine-grained small aggregates of specular hematite and closely associated tiny monazite grains. Tiny fluid inclusions formed in irregular or grain-defining clouds within the quartz of this paragenesis, and not in quartz of the later stages.

2. Quartz

Subsequent quartz crystallised as a massive granular mosaic. Euhedral faces are developed (crustiform texture) where this quartz projected into vughs.

3. Quartz + hematite

Thin colloform laminae of chalcedonic quartz and hematite overgrew the latest euhedral quartz of stage 2. Internal lamination within these colloform bands is defined by very thin hematite-rich laminae. This hematite is cryptocrystalline (submicron-sized, indistinguishable microscopically), in contrast with the better-crystallised specular hematite of stage 1, and it imparts the bright red colour to this part of the sample.

4. Latest quartz

Massive granular quartz, identical to the quartz of stage 2, filled most remaining space. Minor remnant open space (vughs) are observed in the hand sample.

SAMPLE ID : 2065335-A (Parabarana area, Mount Painter Inlier, SA)

STRATIGRAPHY : -

LITHOLOGY : Contact between granite and metasediment

SECTION NO. : 2065335-A

HAND SPECIMEN : The sawn rock sample represents a fine-grained drab yellow-grey rock, in which mineral lamination is defined by alternating, thin, poorly-defined, drab yellow and grey laminae.

ROCK NAME : High-intensity epidote-actinolite-plagioclase altered meta-laminated rock (meta-?sediment)

PETROGRAPHY AND MINERAGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	**Vol %**	**Origin**
Epidote	44	Hydrothermal alteration 2 (after precursor 1)
Actinolite	29	Hydrothermal alteration 2
Plagioclase	25	Hydrothermal alteration 2
Carbonate (calcite)	<1	Hydrothermal alteration 2
Titanite	<1	Hydrothermal alteration 2
Magnetite	Tr	Hydrothermal alteration 2

In polished thin section, this sample displays a massive fine-grained inequigranular alteration texture.

Epidote is abundant. It forms small equant anhedral grains mostly ~0.1-0.4 mm in size. They display the typical optical properties of this mineral: pleochroic pale yellow colour, anomalous interference colours, inclined extinction to cleavage traces. Although distributed throughout the rock, in places the epidote tends to be concentrated in indistinct bands as observed in the hand sample.

Actinolite occurs in significant amount as anhedral weakly pleochroic pale green grains. Many are moderately large, up to ~1.5 mm in size, and poikiloblastically enclose small plagioclase grains.

Plagioclase is moderately abundant, forming small anhedral grains between and within the epidote and actinolite. Some larger anhedral grains ~1-2 mm in size occur in local areas. Moderately developed multiple twinning and low birefringence aids identification of the plagioclase.

Carbonate (calcite) occurs in minor amount as small ragged grains. Mostly it is absent.

Titanite occurs as minor subhedral grains which displays the typical high relief, weak pale pink pleochroism, and extreme birefringence of this mineral. It is sparsely and irregularly scattered through the rock.

Magnetite occurs in trace amount as tiny subhedral to euhedral crystals ~10-20 μm in size. Most occur within actinolite grains.

Minor indistinct discontinuous thin veinlets are observed. They are <0.5 mm thick, and are composed of varied abundances of plagioclase, epidote and calcite.

INTERPRETATION :

This sample displays a pervasive fine-grained inequigranular alteration assemblage of epidote + actinolite + plagioclase + minor others (calcite, titanite, magnetite). The mineral assemblage suggests that alteration occurred at P-T conditions of the greenschist facies, in a static environment (ie no directional stress regime), in the presence of a significant amount of low-CO_2 fluid. The presence of minor indistinct thin discontinuous veinlets provides further support for fluid flow through the rock. The low CO_2 content of the fluid is supported by the very low amount of calcite and the abundance of epidote (which, at greenschist conditions, is stable only in the presence of very low CO_2 in a fluid). No precursor minerals or textures are preserved. This prevents any reasonable discussion of the pre-alteration genesis of the rock. However, the concentration of minerals in indistinct alternating laminae (epidote-rich and actinolite-plagioclase-rich) suggests that the precursor rock may have been a sediment or meta-sediment.

SAMPLE ID : **2065335-B (Parabarana area, Mount Painter Inlier, SA)**

STRATIGRAPHY : -

LITHOLOGY : Contact between granite and metasediment

SECTION NO. : 2065335-B

HAND SPECIMEN : The section offcut captures the contact between two rock types: half of the sample represents a medium to coarse-grained massive crystalline rock composed of abundant blocky anhedral pale pink feldspar grains and ragged drab green ferromagnesian aggregates; the other half of the sample is similar in appearance to sample 2065335-A being composed of indistinct thin laminated bands of dull green grains and dull yellowish grains.

The sample fails to respond to the hand magnet, suggesting magnetite is absent.

ROCK NAME : **Altered intrusive rock and wall rock:**

Actinolite-epidote altered granitoid (?monzonite)

High-intensity epidote-actinolite-plagioclase altered meta-?sediment

PETROGRAPHY AND MINERAGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	**Vol %**	**Origin**
Actinolite-zoisite altered granitoid (?monzonite)		
Alkali feldspar (microperthite)	31	Relict igneous phenocrysts 1
Ilmenite	<1	Relict igneous 1
Zircon	Tr	Igneous 1
Plagioclase	31	Alteration 2 (after precursor 1)
Actinolite	26	Alteration 2
Epidote	10	Alteration 2
Titanite	<1	Alteration 2
High-intensity epidote-actinolite-plagioclase altered meta-?sediment		
Epidote	35	Alteration 2 (after precursor 1)
Actinolite	34	Alteration 2
Plagioclase	30	Alteration 2
Titanite	<1	Alteration 2
Carbonate (calcite)	Tr	Alteration 2

In polished thin section, this sample displays similar minerals but different textures in two different parts of the rock.

Actinolite-zoisite altered granitoid (?monzonite) retains some of its primary massive coarse-grained granitoid texture.

Alkali feldspar is moderately abundant. It forms large subhedral prismatic crystals ~6 mm in size, composed of varied abundances of intergrown thinly twinned albite and untwinned orthoclase. Together, the alkali feldspar appears to represent igneous microperthite crystals, somewhat modified by subsequent alteration.

Plagioclase occurs as subhedral blocky twinned prisms that are smaller (mostly ~2 mm long) than the alkali feldspar crystals. Some occur as inclusions within the larger alkali feldspar prism sites.

Actinolite is moderately abundant. It forms large optically continuous grains that occupy large patches between the feldspar prisms. It displays the typical pale green pleochroism and low to moderate birefringence of this mineral. Epidote forms equant anhedral pale yellow grains which are irregularly distributed through the large actinolite grains. A very small amount of epidote forms small grains within the altered plagioclase prisms.

Ilmenite is observed as local anhedral grains mostly ~0.4 mm in size, distributed irregularly through the actinolite-epidote aggregates. They are partly replaced around margins by fine-grained titanite, and appear to represent a relict primary igneous phase. Titanite also occurs as discrete subhedral larger crystals.

Zircon is uncommon, forming small euhedral doubly terminated prismatic crystals ~50-100 μm in size. They display the typical high relief, lack of colour, high birefringence and parallel extinction of this mineral. They occur within the large actinolite grains, and also at margins of, and as inclusions within, the ilmenite grains.

High-intensity epidote-actinolite-plagioclase altered meta-?sediment represents the other half of the section. It is similar in mineralogy and texture to the previous sample (2065335-A). It is composed of a massive inequigranular mosaic of anhedral pale yellow epidote grains, larger anhedral pale green actinolite grains, and small ragged twinned plagioclase grains located between the actinolite and epidote but also as inclusions within the actinolite. Titanite is present in minor amount as discrete subhedral grains. Carbonate (calcite) forms uncommon small ragged grains.

INTERPRETATION :

This sample is considered to capture the contact between granitoid and wall rock or xenolith.

The granitoid was originally composed of the coarse-grained massive assemblage of alkali feldspar + plagioclase + ferromagnesians (possibly ?pyroxene, ?amphibole) + minor others (ilmenite, zircon). The presence of primary ilmenite suggests that the granitoid magma was reduced. The alkali feldspar formed larger blocky prismatic crystals, lending a subporphyritic texture to the granitoid. The rock has suffered selective pervasive alteration in response to infiltration by a moderate volume of hydrothermal fluid at greenschist facies P-T conditions, but without a directed regional stress regime (ie static conditions). This produced the massive selective replacement assemblage: all ferromagnesians were replaced by actinolite + epidote; plagioclase was replaced by new optically continuous plagioclase; alkali feldspar mostly remained as such with exsolution of the Na-feldspar and K-feldspar components to produce microperthite; ilmenite was partly replaced around crystal margins by fine-grained titanite; primary zircon survived. Positive identification of the primary granitoid rock type remains uncertain because of the moderate intensity of alteration. A monzonitic composition is inferred from the moderately high abundance of alkali feldspar, moderately high abundance of primary ferromagnesians, and absence of quartz. However, it remains possible that the granitoid contained primary quartz which was completely destroyed by a hydrothermal fluid undersaturated in silica.

The wall rock suffered complete pervasive replacement by a similar alteration assemblage in different proportions: epidote + actinolite + plagioclase + minor others (titanite, calcite). The presence and abundance of epidote confirms that the fluid was low in CO_2. No precursor minerals or textures of the protolith are preserved.

The nature of the contact between the granitoid and the adjacent rock has been obscured, but it is inferred to represent an intrusive contact of granitoid into sedimentary or meta-sedimentary wall rocks.

SAMPLE ID : **2065335-C (Parabarana area, Mount Painter Inlier, SA)**

STRATIGRAPHY : -

LITHOLOGY : Contact between granite and metasediment

SECTION NO. : 2065335-C

HAND SPECIMEN : The sample represents a massive coarse-grained crystalline rock composed of large blocky prismatic pale pink feldspar crystals ~1-2 cm in size, and a lesser amount of drab green ragged patches (altered ferromagnesian grains).

The sample fails to respond to the hand magnet, suggesting magnetite is absent (but see magnetite below).

ROCK NAME : **Actinolite-epidote altered granitoid (?monzonite)**

PETROGRAPHY AND MINERAGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	**Vol %**	**Origin**
Alkali feldspar (microperthite)	48	Relict igneous 1
Ilmenite	<1	Relict igneous 1
Zircon	Tr	Igneous 1
Plagioclase	20	Alteration 2 (after plagioclase 1)
Actinolite	20	Alteration 2
Epidote	10	Alteration 2
Titanite	<1	Alteration 2
Magnetite	Tr	Alteration 2

In polished thin section, this sample displays a partly preserved massive subporphyritic igneous texture, modified by selective pervasive alteration effects.

Alkali feldspar was abundant, forming large squat prismatic crystals. The relatively large size of some (~1-2 cm) lends a subporphyritic texture to the granitoid. All of the alkali feldspar crystals are now occupied by a microperthitic intergrowth of thinly twinned albite and massive orthoclase, each forming optically continuous intergrowths.

Plagioclase (albitic) also occurs as thinly twinned replacements of precursor plagioclase prisms. These were smaller (~2-5 mm) than the alkali feldspar crystals, and some occurred as inclusions within the larger alkali feldspar crystals.

Actinolite is moderately abundant. It occurs as pleochroic pale green large anhedral grains which occupy patches between the larger feldspar crystals. Small pleochroic pale yellow epidote grains are irregularly distributed through the optically continuous actinolite patches, and together the actinolite and epidote are readily interpreted as having replaced precursor primary ferromagnesian minerals (?amphibole, ?pyroxene) but none is preserved for confirmation. Magnetite is rare, occurring as minute cubic crystals ~10-20 μm in size, located in some of the actinolite-epidote aggregates.

Ilmenite occurs in minor amount as anhedral grains and subhedral crystals located within the (now-altered) ferromagnesian sites. The ilmenite displays its typical pale pinkish colour under plane polarised reflected light, and all grains have suffered partial replacement around margins by fine-grained titanite. Titanite also occurs as discrete subhedral to euhedral small crystals.

Zircon occurs in trace amount as small euhedral colourless terminated prisms ~100-200 µm long. They occur within the actinolite-zoisite aggregates (ie within altered ferromagnesian grain sites), where they tend to occur at margins of some of the relict ilmenite grains.

INTERPRETATION :

This sample is considered to have initially crystallised as a massive coarse-grained granitoid, possibly of monzonitic type composed of alkali feldspar + plagioclase + ferromagnesians (?amphibole, ?pyroxene) + minor others (ilmenite, zircon). The presence of ilmenite indicates that the granitoid magma was reduced. The large prisms of alkali feldspar lend a subporphyritic texture to the granitoid.

The rock was infiltrated by a moderate volume of aqueous fluid at P-T conditions of the greenschist facies. This caused selective pervasive replacement by the alteration assemblage of albite + actinolite + epidote + minor titanite + trace magnetite. The massive texture of the alteration minerals indicates that they formed in a static environment (ie no directed stress regime). In more detail:

i) The primary alkali feldspar crystals retained their physical identity but inverted to a microperthitic intergrowth of albite + orthoclase.

ii) The ferromagnesian grains were completely replaced by actinolite + epidote + minor titanite; none is preserved.

iii) The primary ilmenite grains suffered partial replacement around margins by fine-grained titanite, and small discrete titanite crystals also formed elsewhere in the altered ferromagnesian grain sites.

iv) Primary zircon was unaffected.

SAMPLE ID : 2065336 (Mt Gee Epithermal System, Arkaroola, SA)

STRATIGRAPHY : Mount Gee Sinter

LITHOLOGY : ?sintery rock

SECTION NO. : 2065336

HAND SPECIMEN : The rock sample represents a porous rock composed of subparallel indistinct discontinuous thin laminae alternately red and yellow.

ROCK NAME : Goethite-clay (weathered) rock

PETROGRAPHY AND MINERAGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	Vol %	Origin
Goethite	35	Weathering 2 (after precursor 1)
Clays	30	Weathering 2
Voids	35	Solution cavities 2

In polished thin section, this sample displays a porous colloform texture.

Goethite is abundant. It is concentrated in patches and discontinuous subparallel bands ~0.5-3.0 mm thick. Within the patches and bands, the goethite is concentrated in thin colloform laminae ranging ~2-100 µm thick. The laminae display intricate colloform textures. All of the goethite displays the typical colour of this mineral: deep red colour under plane transmitted light, and medium to dull grey colour under plane polarised reflected light.

Clays occur in similar abundance to goethite. It displays a yellow to orange-red colour under plane transmitted light, with low-order interference colours typical of clays. Like the goethite, it displays thinly laminated texture, and appears to have formed by overgrowth of the earlier goethite, and locally lines the abundant remnant solution cavities.

INTERPRETATION :

This sample formed as an unknown precursor rock, possibly with lamination such as might occur in epithermal deposits. All precursor minerals have been completely replaced in response to circulation and dissolution by near-surface meteoric waters. This generated abundant intricately colloform goethite + clays + remnant voids. Microtextures and structures suggest that the weathering minerals formed in two paragenetic stages:

1. Goethite

Dissolution of the precursor rock produced goethite + solution cavities. The patchy to subparallel laminated structure of the goethite allows it to have formed by complete replacement of precursor laminated rock (eg ?siliceous sinter). Abundant solution cavities formed to produce a highly porous ferruginous rock.

2. Clay

Clay was deposited subsequently, as thinly laminated overgrowths of the goethite and linings of the remnant solution cavities.

SAMPLE ID : 2065337 (Mt Gee Epithermal System, Arkaroola, SA)

STRATIGRAPHY : -

LITHOLOGY : Fault breccia

SECTION NO. : 2065337

HAND SPECIMEN : The rock sample represents a massive fragmental rock composed of small to larger fragments several millimetres to ~1 cm in size. The fragments are variably red and translucent grey to white in colour, in a fine-grained hard (siliceous) massive drab yellow-brown matrix. Minor solution cavities display thin trail-like shapes.

ROCK NAME : Weakly weathered, siliceous hydrothermal breccia

PETROGRAPHY AND MINERAGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	Vol %	Origin
Quartz (coarse-grained, subradiating)	15	Epithermal fragments 1a
Quartz (very fine-grained, massive)	10	Epithermal fragments 1a
Hematite	Tr	Epithermal fragments 1a
Monazite	Tr	Epithermal fragments 1a
Quartz (fine-grained, microcrystalline)	69	Epithermal cement 1b
Clay (?kaolinite)	2	Epithermal cement 1b
Goethite/hematite	2	Weathering 2
Clay	1	Weathering 2

In polished thin section, this sample displays a matrix-supported fragmental (breccia) texture, defined by angular clasts scattered sparsely through abundant fine-grained massive hydrothermal cement.

Clasts occur in minor amount, and different types are recognised:

i) Some clasts up to ~1 cm in size are composed entirely of coarse-grained subradiating quartz aggregates. No other minerals are observed in these clasts, which are identical texturally to the coarse-grained subradiating quartz observed in other samples in this collection.

ii) Some clasts are composed of massive granular quartz, patches of fine-grained massive quartz pervaded by submicron hematite clouding, minor bladed hematite crystals, and uncommon small monazite prisms. These clasts represent partly-weathered epithermal deposits. Some of these clasts are also clouded by very fine-grained massive clay.

Quartz dominates the matrix enclosing the clasts. It forms a massive cement which grades from very fine-grained massive microgranular mosaics into slightly coarser-grained quartz with indistinct bladed crystals up to ~100 μm long. Minor clay occurs as very fine-grained massive colourless patches scattered sparsely through the quartz mosaic; tiny quartz crystals project into the clay, suggesting the clay formed as late-formed vugh-fillings in the quartz mosaic.

INTERPRETATION :

This sample is considered to have formed as a matrix-supported breccia, possibly a primary siliceous breccia in an epithermal sinter deposit. Stages of rock formation are interpreted as follows:

1. Quartz + hematite + monazite

Early-formed epithermal sintery deposits were composed of varied abundances of quartz, minor hematite and trace monazite. Some of these deposits were composed of massive coarse-grained subradiating quartz, and other deposits were composed of intergrown quartz + hematite + trace monazite. Both of these differently textured epithermal deposit types are observed elsewhere in single samples (eg 2065334-A, -B). Note that any mineralisation in this rock formed in this early stage of epithermal deposit formation, and not in the later breccia cement.

2. Fragmentation

The early-formed epithermal deposits were fragmented and redistributed in the surficial environment.

3. Cementation

Infiltration by new siliceous hydrothermal fluid resulted in cementation of the earlier-formed fragments in a massive matrix of quartz + minor clay. Quartz formed a massive to weakly bladed fine-grained cement, accompanied by minor clay in small vughs. No mineralisation is observed in this late-formed assemblage.

4. Weathering

Subsequent infiltration by near-surface meteoric waters produced minor goethite + clays, mainly by selective oxidation of some of the hematite-bearing clasts.

SAMPLE ID : 2065338 (Mt Gee Epithermal System, Arkaroola, SA)

STRATIGRAPHY : -

LITHOLOGY : Fault breccia

SECTION NO. : 2065338

HAND SPECIMEN : The rock sample displays a fragmental (breccia) texture, defined by moderately large angular clasts up to ~1-2 cm in size that are variably red to white and translucent grey, in a fine-grained massive hard siliceous matrix that is drab pale yellow.

ROCK NAME : Weakly weathered, siliceous hydrothermal breccia

PETROGRAPHY AND MINERAGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	Vol %	Origin
Quartz (coarse-grained)	10	Epithermal clasts 1a
Hematite	<1	Relict epithermal clasts 1a
Monazite	Tr	Epithermal clasts 1a
Quartz (fine-grained, massive)	78	Epithermal cement 1b
Clay (fine-grained, vugh-filling)	5	Epithermal cement 1b
Hematite	<1	Weathering 2
Voids	5	Weathering 2

In polished thin section, this sample displays a massive fragmental texture, modified by weak oxidation overprint.

Clasts occur in minor amount. They are ~4-6 mm in size and angular in shape. They are composed of similar minerals in different proportions:

i) Coarse-grained quartz dominates the clasts. The quartz mostly displays a massive granular texture, but in some clasts it is subradiating.

ii) Hematite occurs in minor to moderate abundance. It forms small to large bladed crystals up to ~0.5 mm long. Some hematite forms dense clouds of submicron-sized specks, most likely of overprinting weathering origin.

iii) Monazite occurs in varied abundance, from absent to ~2%. It forms small to larger euhedral prisms up to ~0.4 mm in size. They display the typical high relief, lack of colour, moderate birefringence and inclined extinction of this mineral.

Matrix encloses the clasts, and different components are recognised:

i) Quartz is abundant. It forms a massive cement composed of very fine-grained massive microcrystalline mosaic, which quickly grades into slightly coarser-grained quartz with indistinct bladed crystal forms.

ii) Clay occurs in minor amount as very fine-grained massive fillings in small ragged vughs that are irregularly distributed through the matrix. In places, some of these clay-filled vughs are lightly stained orange to red by hematite stain.

INTERPRETATION :

This sample is considered to have formed as an epithermal fragmental deposit (breccia). Textures allow interpretation of stages of formation:

1. Early quartz + hematite + monazite

Initial hydrothermal deposits in the epithermal environment were composed of coarser-grained quartz + minor hematite + monazite.

2. Fragmentation

The early hydrothermal deposits were physically disrupted.

3. Cementation

On-going flow of siliceous hydrothermal fluid through the epithermal terrain produced a fine-grained massive cement (quartz + clay) which was deposited around the earlier clasts.

4. Weathering

Circulation of a small amount of surficial meteoric waters generated minor new hematite as diffuse clouding in some of the hematite-bearing epithermal clasts.

SAMPLE ID : 2065339 (Mt Gee Epithermal System, Arkaroola, SA)

STRATIGRAPHY : Mount Gee Sinter

LITHOLOGY : -

SECTION NO. : 2065339

HAND SPECIMEN : The grab rock sample captures the sharp contact between two rock types: massive medium-grained pink altered granitoid, and banded rock composed of alternating white and dark grey to black bands subparallel to the contact with the granitoid. It is not evident from the sample whether the banded rock forms a vein within granitoid wall rock, or whether the granitoid occurs as a clast within the banded rock.

The granitoid fails to respond to the hand magnet, but the banded rock responds weakly to the hand magnet suggesting minor magnetite is present.

ROCK NAMES : Altered granitoid

Banded quartz-hematite-monazite epithermal rock

PETROGRAPHY AND MINERAGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	Vol %	Origin
Altered granitoid		
K-feldspar (microcline)	58	Relict igneous 1
Quartz	35	Igneous 1
Ilmenite	<1	Relict igneous 1
Zircon	Tr	Igneous 1
Monazite	Tr	?Igneous 1 / ?alteration 2
Albite	3	Alteration 2 (after plagioclase 1)
Sericite	2	Alteration 2 (after plagioclase 1)
Rutile	Tr	Alteration 2 (after ilmenite 1)
Quartz	<1	Thin fracture seals 2
Banded quartz-hematite-monazite epithermal rock		
Quartz (inequigranular, subradiating)	90 (65-99)	Epithermal 2
Hematite (bladed, with minor magnetite)	10 (Tr-35)	Epithermal 2
Monazite	Tr (0-Tr)	Epithermal 2

In polished thin section, this sample displays different minerals and textures in two different rock types:

Altered granitoid retains its massive allotriomorphic granitoid texture.

Primary K-feldspar grains ~2-4 mm in size are blocky but anhedral in form. They display the thin combined albite and pericline twinning characteristic of microcline. These K-feldspar grains are readily interpreted as primary K-feldspar grains (orthoclase) which have suffered inversion to the lower-temperature structural state of microcline. Some of the K-feldspar grains are quite clear, but most display partial to severe clouding by minute (submicron-sized) hematite specks and minor sericite flecks.

Primary quartz is moderately abundant. It forms equant anhedral grains, some with ovoid shapes, and tendency to form aggregates. Most grains display weak shadowy strain extinction of mild deformation origin.

Albite is present in minor amount as optically continuous replacements of blocky grains which are readily interpreted as altered primary plagioclase. All are lightly clouded by tiny sericite flecks and tiny hematite specks.

Ilmenite occurs in minor amount as subhedral bladed grains and anhedral grains, mostly ~0.5-1.0 mm in size. All have suffered partial to complete replacement by hematite and fine-grained granular rutile.

Zircon is observed as uncommon small terminated colourless prisms, located in quartz, K-feldspar and in close association with ilmenite grains. Trace monazite is observed as small blocky crystals, in places closely associated with zircon and ilmenite, but minor larger equant grains of monazite occur near the contact with the banded rock, and may represent alteration grains.

Cutting the rock are minor thin discontinuous fractures that are sealed by anhedral quartz grains.

Banded quartz-hematite-monazite epithermal rock lies in sharp contact with the altered granitoid. It is composed of bands ranging away from the contact:

1. Quartz + hematite

A thin band ~1 mm wide but variable width is composed of small quartz grains with subradiating internal microstructure, minor small bladed hematite crystals, and trace monazite as small blocky crystals.

2. Quartz

A band ~2 mm wide is composed solely of quartz, which forms larger subhedral bladed grains ~0.8 mm long with subradiating internal microstructure. Minute fluid inclusions are concentrated in diffuse clouds, in places outlining crystal growth planes in the quartz, but are too small for useful petrographic observations. Terminated crystals display crustiform texture where they project into vughs aligned in the trace of the banding; these terminated crystals lack fluid inclusions.

3. Quartz + hematite + monazite

A band ~5 mm wide (dark grey to black in hand sample) is composed of anhedral quartz grains ~0.5 mm in size with weak internal subradiating microstructure, enclosing euhedral bladed hematite crystals ~0.4-1.0 mm long which are aligned with the banding. The polish of the hematite is poor, preventing precise optical observation, but it is likely that minor relict primary magnetite is preserved within the hematite crystals as supported by the weak magnetic response to the hand magnet. Tiny monazite crystals ~30-100 µm in size are sparsely sprinkled through the quartz.

4. Quartz + hematite

A thick band (white in hand sample) is composed mostly of quartz, which forms large anhedral grains ~2-4 mm in size, in places forming massive aggregates but elsewhere displaying a preferred orientation across the banding. All of these quartz grains display subradiating internal microstructure. Minute fluid inclusions lightly cloud the quartz in places, defining crystal growth zones. Hematite occurs locally in trace amount as small subhedral bladed crystals. No monazite is observed.

INTERPRETATION :

This sample captures two rock types, altered granitoid and banded epithermal rock. Their relationships are unclear from the hand sample.

The granitoid is interpreted to have crystallised as a massive, medium-grained leuco-monzogranite to leuco-syenogranite, composed of K-feldspar + quartz + minor plagioclase + trace others (ilmenite, zircon, ?monazite). It has suffered weak selective alteration effects, producing new albite + sericite + rutile. In more detail, primary K-feldspar inverted to microcline ± hematite, and plagioclase was replaced by albite + sericite + trace hematite. Some primary ilmenite was replaced by hematite + rutile. Primary quartz and zircon were unaffected.

The banded epithermal rock may have formed as a space-filling vein within the granitoid, or may have formed as a cement enclosing the granitoid as a clast. Crystallisation of hydrothermal fluid produced an open-space deposit composed of quartz + hematite + monazite. Banding within the deposit was defined by varied abundances of the 3 minerals: quartz + hematite near the granitoid wall, quartz with crustiform vughs, quartz + hematite + monazite in which abundant hematite crystals lie subparallel to banding, and quartz + trace hematite distant from the granitoid wall. All of the quartz displays similar characteristics in all bands, with subhedral grain shapes and internal subradiating microstructure, with or without varied development of minute fluid inclusions. The similar quartz textures across all bands and presence of hematite in most bands suggests that the banding formed by crystallisation of different pulses of compositionally similar hydrothermal fluid containing abundant dissolved silica, significant Fe, and minor REE and P components now hosted by monazite. The likely presence of minor magnetite in the hematite crystals suggests that initial crystallisation produced magnetite, but oxidation state of the fluid quickly progressed into the hematite-only field.

SAMPLE ID : 2065340 (Mt Gee Epithermal System, Arkaroola, SA)

STRATIGRAPHY : Mount Gee Sinter

LITHOLOGY : -

SECTION NO. : 2065340

HAND SPECIMEN : The rock sample represents a massive reddish grey to white rock composed of abundant large angular patches ranging from several millimetres to ~1 cm in size composed of abundant metallic lustrous dark grey hematite and reddish patches, enclosed by translucent grey to white quartz with local small vughs.

The sample fails to respond to the hand magnet, suggesting magnetite is absent.

ROCK NAME : Quartz-hematite-monazite epithermal rock

PETROGRAPHY AND MINERAGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	Vol %	Origin
Quartz (finer-grained, subhedral, subradiating)	55	Epithermal 1a
Hematite	20	Epithermal 1a
Monazite	Tr	Epithermal 1a
Quartz (coarser-grained, subradiating)	25	Epithermal 1b

In polished thin section, this sample displays a massive open space-filling epithermal texture.

Quartz occurs in two textural forms:

i) Much quartz occurs as fine-grained massive microcrystalline mosaics and accompanying small bladed grains with subradiating texture. This quartz occupies large patches many millimetres in size (dark patches in hand sample).

ii) A lesser amount of quartz occurs as larger subhedral bladed grains with strong subradiating internal microstructure. These grains forms a matrix which encloses the quartz of i) above. In places, the quartz grains project with euhedral terminations into ragged vughs of varied shapes. Minute fluid inclusions are concentrated in diffuse clouds in the quartz, in places defining crystal growth zones, but at <2 μm in size are too small for useful petrographic observations.

Hematite is moderately abundant, and occurs only in the quartz of i) above. The hematite forms randomly oriented bladed crystals which range widely in size from ~0.2 mm up to ~2 mm long. It also forms tiny bladed grains which are concentrated in small ragged aggregates.

Monazite occurs in trace amount as small blocky prisms ~50-150 μm in size. They occur only in the fine- to slightly coarser-grained quartz in close association with hematite. None occurs in the later-formed coarser-grained quartz.

INTERPRETATION :

This sample is considered to have crystallised from hydrothermal fluid under epithermal (low P) conditions. This produced a massive assemblage of quartz + hematite + trace monazite. Textures suggest that early crystallisation of the silica-Fe-P-REE-bearing fluid produced finer-grained intergrown quartz + hematite +

monazite, enclosed by coarser-grained late-formed quartz which locally projects into small vughs. The sample displays an apparent fragmental texture in hand sample, but this is only apparent: continuous crystallisation of hydrothermal fluid has produced the earlier darker patches in the hand sample which are emphasised by their abundant hematite, which is absent from the later-formed overgrowing coarser-grained quartz.

SAMPLE ID : 2065341 (Mt Gee Epithermal System, Arkaroola, SA)

STRATIGRAPHY : Mount Gee Sinter

LITHOLOGY : -

SECTION NO. : 2065341

HAND SPECIMEN : The rock sample represents a massive black and white patchy rock, composed of subequal proportions of subrounded to ragged aggregates of metallic dark grey specular hematite (crystalline, hard, red streak) mostly several millimetres to ~1 cm in size, in a white siliceous matrix with minor small vughs.

The sample fails to respond to the hand magnet, suggesting magnetite is absent.

ROCK NAME : Quartz-hematite-monazite epithermal rock

PETROGRAPHY AND MINERAGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	Vol %	Origin
Quartz (finer-grained, bladed, subradiating)	29	Epithermal 1a
Hematite	20	Epithermal 1a
Monazite	<1	Epithermal 1a
Pyrite	Tr	Epithermal 1a (inclusions in hematite)
Chalcopyrite	Tr	Epithermal 1a (inclusions in hematite)
Quartz (coarser-grained, bladed, subradiating)	48	Epithermal 1b
Hematite	Tr	Epithermal 1b
Monazite	Tr	Epithermal 1b
Voids	1	Epithermal 1b

In polished thin section, this sample displays a massive, inequigranular, space-filling texture with local crustiform vughs.

Quartz dominates the rock, and two textural types are distinguished:

i) A significant amount of quartz occurs as smaller, subhedral, bladed grains mostly ~0.2-0.4 mm in size. They are concentrated in ragged patches many millimetres in size. Tiny ragged fluid inclusions are loosely concentrated in small diffuse patches, but are too small for useful petrographic observations.

ii) Much quartz occurs as larger, subhedral bladed grains mostly ~1-2 mm long, but in places up to ~4 mm. They form a matrix enclosing the finer-grained quartz patches. In places, the larger crystals project with euhedral terminations into vughs up to several millimetres in size. Small fluid inclusions with ragged shapes are moderately abundant. Many are too small or too poorly shaped for good petrographic observations, but some appear to be filled by dark fluid (possibly CO_2-rich) and others appear to be filled by clear fluid (H_2O-rich). It is possible that two populations of fluids are captured, suggesting that vapour phase separation (boiling) was occurring during precipitation of the quartz.

Hematite is moderately abundant. It mostly occurs in the fine-grained quartz patches, where it forms small to large acicular to bladed crystals (specular hematite) ~0.2-2.0 mm long. They are randomly oriented, and tend to be concentrated in aggregates. A small amount of hematite occurs as smaller crystals in the later-formed coarser-grained quartz, but is absent from the latest crustiform quartz.

Monazite is present in minor amount, mostly in the quartz-hematite patches, but also in trace amount in the coarser-grained quartz. The monazite forms small euhedral blocky prisms mostly ~0.1-0.2 mm in size, but locally up to ~0.4 mm. They display the high relief, colourless to very pale yellowish colour, and moderate birefringence typical of this mineral.

Pyrite and chalcopyrite occur as rare small inclusions within the larger hematite crystals. They are absent elsewhere (ie they don't form discrete crystals in the quartz).

INTERPRETATION :

This sample displays minerals and textures which indicate crystallisation of hydrothermal fluid under epithermal conditions. This produced the massive assemblage of quartz + hematite + monazite. Textures and mineral distribution allow identification of two principal stages of mineral formation (parageneses):

1. Quartz + hematite + monazite + trace pyrite + chalcopyrite

Finer-grained patches formed as intergrown small bladed quartz grains, small to larger hematite crystals with trace sulfide inclusions, and minor small monazite crystals.

2. Quartz + trace hematite + monazite

Late-formed quartz formed larger bladed grains which enclose the finer-grained earlier-formed quartz-hematite-monazite patches. Trace amounts of hematite and monazite also formed in this quartz. Latest quartz crystallised as crustiform crystals projecting into minor residual vughs. It is notable that the quartz of this stage and the earlier stage share similarities: both stages of quartz display bladed subhedral grain shapes (although the later stage is coarser grained), and both stages of quartz contain tiny fluid inclusions with possible different types suggesting vapour phase separation (ie boiling).

The mineralogical similarities, together with the textural and fluid inclusion similarities, suggest that the rock formed from a single oxidised silica-Fe-P-REE-bearing hydrothermal fluid but in two stages of mineral formation.

SAMPLE ID : **2065342 (Mt Gee Epithermal System, Arkaroola, SA)**

STRATIGRAPHY : Mount Gee Sinter

LITHOLOGY : -

SECTION NO. : 2065342

HAND SPECIMEN : The rock sample represents a massive patchy rock composed of metallic dark grey and red ragged patches and discontinuous bands, in a matrix of translucent grey to white quartz which locally displays crustiform texture.

The sample fails to respond to the hand magnet, suggesting magnetite is absent.

ROCK NAME : **Quartz-hematite-monazite epithermal deposit**

PETROGRAPHY AND MINERAGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	**Vol %**	**Origin**
Quartz (fine-grained, bladed, subradiating)	35	Epithermal 1a
Hematite	15	Epithermal 1a
Monazite	<1	Epithermal 1a
Quartz (coarse-grained, bladed, subradiating)	49	Epithermal 1b
Hematite	Tr	Epithermal 1b
Monazite	Tr	Epithermal 1b

In polished thin section, this sample displays a massive, mineralogically patchy and inequigranular epithermal texture.

Quartz is abundant, and two textural types are distinguished:

i) A significant amount of quartz occurs as small anhedral and subhedral grains, mostly ~0.1-0.2 mm in size. In places the quartz grades into slightly larger grains ~0.4 mm long with subradiating internal microtexture. They are concentrated in small to larger patches ~2-5 mm in size distributed through the rock. Tiny fluid inclusions are distributed in diffuse patches through the quartz. They display ragged shapes but are too small and too turbid in appearance to provide better petrographic observations. A minor proportion of coarser-grained quartz occurs in these finer-grained patches; this quartz displays subhedral to euhedral crystal forms, and lacks the fluid inclusions in the bladed quartz.

ii) Much quartz occurs as larger bladed grains mostly ~1-2 mm long. They form a matrix enclosing the finer-grained quartz patches. All of the grains display strong internal subradiating microtexture, and contain abundant minute ragged turbid fluid inclusions which tend to be concentrated along crystal growth zones in each quartz grain. The fluid inclusions are too small for better petrographic observations.

Hematite is moderately abundant. Most occurs in the finer-grained quartz-rich patches, where it forms larger to smaller bladed crystals ranging from ~0.8 mm down to ~20 μm long. Some hematite also occurs as submicron-sized specks which are concentrated in loose clouds; this hematite is responsible for the red appearance in patches through the hand sample.

Monazite is present in minor amount, mostly in the quartz-hematite-rich patches. It forms small to larger euhedral crystals mostly ~50-100 μm in size, but some range up to ~0.4 mm in size. They display the high relief, very pale yellowish colour, and moderate birefringence of this mineral.

INTERPRETATION :

This sample crystallised from siliceous-Fe-P-REE-bearing hydrothermal fluid under open space-filling epithermal conditions. Early-crystallised patches were composed of quartz + hematite + monazite, and later-formed matrix crystallised with the same assemblage. Mineral abundances and textures differ: the early-formed patches contain finer-grained quartz and more abundant hematite and monazite, whereas the later-formed matrix is dominated by coarser-grained quartz and contains only trace hematite and monazite.

SAMPLE ID : 2065343-A (Mt Gee Epithermal System, Arkaroola, SA)

STRATIGRAPHY : Mount Gee Sinter

LITHOLOGY : Rounded hem. in MGS

SECTION NO. : 2065343-A

HAND SPECIMEN : The rock sample is composed of moderately abundant small to larger (~2-5 mm) aggregates of lustrous metallic hematite and closely associated very fine-grained red patches, enclosed by translucent grey to white hard quartz.

The sample fails to respond to the hand magnet, suggesting magnetite is absent.

ROCK NAME : Quartz-hematite-monazite epithermal rock

PETROGRAPHY AND MINERAGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	Vol %	Origin
Quartz (subhedral crystals)	2	Epithermal 1a
Quartz (bladed, subradiating)	81	Epithermal 1b
Hematite	15	Epithermal 1b
Monazite	Tr	Epithermal 1b
Hematite	Tr	Epithermal 1c (late vugh fillings)
Sericite	Tr	Epithermal 1c (late vugh fillings)
Voids	1	Epithermal 1c (remnant vughs)

In polished thin section, this sample displays a massive open space-filling epithermal texture.

Quartz dominates the rock, and different textural types are distinguished:

i) A small amount of quartz occurs as stumpy subhedral crystals ~0.5-1.0 mm in size. They are sparsely scattered through the rock, and are free of inclusions and internal subradiating microtexture.

ii) Most quartz occurs as small to larger subhedral grains with subradiating internal microtexture. They range in size from small grains ~0.2-0.4 mm concentrated in diffuse patches, to larger grains ~1-2 mm long. All of these grains contain abundant small fluid inclusions which are turbid in appearance, but are too small for useful petrographic observations. They tend to be concentrated in diffuse zones loosely constrained by crystal growth zones in each quartz grain. In places, this coarser-grained quartz projects as euhedral crystals into small vughs.

Hematite is moderately abundant. It occurs as randomly oriented tiny to larger crystals ranging in size from ~20 μm up to ~2 mm. Some form discrete crystals, but others are concentrated in fine-grained aggregates. In places, minute crystals just microns in size are concentrated in small aggregates that display the deep red colour typical of thin hematite under plane transmitted light; this very fine-grained hematite is responsible for the reddish patches observed in the hand sample. Most of the hematite is intergrown with finer-grained quartz patches, and minor hematite occurs in the coarser-grained bladed quartz grains.

Monazite is present in trace amount. It forms small euhedral prisms, some with blocky shapes and others with more prismatic shapes. They display the typical high relief, very pale water-clear yellowish colour, and moderate birefringence of this mineral. Most are very small, 20-100 μm in size, but some larger crystals ~0.4-0.8 mm in size are observed. Most of the monazite occurs within the aggregates of finer-grained quartz and hematite crystals, but some monazite also occurs in the coarser-grained areas richer in quartz.

Uncommon small vughs ~2-5 mm in size are very sparsely scattered through the rock. Some remain as open space, but others are thinly lined by very fine-grained hematite with central filling of fine-grained massive sericite.

INTERPRETATION :

This sample is considered to have crystallised from silica-Fe-P-REE-bearing hydrothermal fluid under open space-filling epithermal conditions. This produced a massive assemblage of quartz + hematite + monazite + trace sericite. Paragenetic stages of crystallisation are recognised from mineral associations and textures:

1. Early quartz

Minor early quartz formed as euhedral small crystals. These crystals are free of inclusions (both mineral and fluid inclusion types) in contrast with the abundant later quartz.

2. Quartz + hematite + monazite

A significant proportion of the rock crystallised as scattered patches composed of fine-grained quartz + hematite + minor monazite. The quartz is bladed and contains subradiating microtexture, and contains tiny turbid fluid inclusions along crystal growth zones.

3. Quartz ± minor hematite ± monazite

Much of the remainder of the rock crystallised as coarser-grained quartz, with the same bladed grain shape, internal subradiating microtexture and fluid inclusions as observed in the earlier finer-grained quartz. Minor hematite and magnetite crystallised in this assemblage.

4. Sericite + hematite

A late hydrothermal fluid of different type, containing dissolved SiO_2-Al-K-Fe, infiltrated the rock producing thin fine-grained hematite rims around some vughs, and filling the remainder of some vughs with fine-grained sericite. Other vughs remained unfilled, suggesting only a small amount of this fluid infiltrated the rock in particular places and not elsewhere.

Stages 1-3 are considered to have crystallised from a single hydrothermal fluid. The fluid quickly became saturated with respect to SiO_2, producing the minor early quartz crystals, and then additionally became saturated with respect to hematite and monazite, which both formed in close association with finer-grained bladed quartz. The fluid may then have become depleted in Fe, P and REE, because the latest stage of the mineralisation assemblage is quartz-rich and contains only a minor amount of hematite and monazite. The presence of tiny fluid inclusions in the abundant quartz of stages 2 and 3 possibly suggests that vapour phase separation (boiling) may have occurred in the fluid during these stages of crystallisation. The last vugh-filling stage displays a different mineral assemblage and texture, and most likely formed by circulation of a small amount of a different fluid lacking the P and REE components of the principal hydrothermal fluid.

SAMPLE ID : 2065343-B (Mt Gee Epithermal System, Arkaroola, SA)

STRATIGRAPHY : Mount Gee Sinter

LITHOLOGY : Rounded hem. in MGS

SECTION NO. : 2065343-B

HAND SPECIMEN : The rock sample is composed of abundant small grains and aggregates of metallic dark grey and diffuse red patches of hematite, in translucent grey to white siliceous matrix.

The sample fails to respond to the hand magnet, suggesting magnetite is absent.

ROCK NAME : Quartz-hematite-monazite epithermal rock

PETROGRAPHY AND MINERAGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	**Vol %**	**Origin**
Quartz (clean, subhedral)	1	Epithermal 1a
Quartz (bladed, subhedral, subradiating)	78	Epithermal 1b
Hematite	15	Epithermal 1b
Monazite	<1	Epithermal 1b
Pyrite	Tr	Epithermal 1b (rare inclusions in hematite)
Quartz (bladed, subhedral, subradiating)	5	Epithermal 1c

In polished thin section, this sample displays a massive space-filling epithermal texture.

Quartz dominates the rock, and different textural types are distinguished:

i) Minor quartz occurs as subhedral crystals <1 mm in size. They are devoid of inclusions of both mineral and fluid types, and lack any internal microstructures (ie they extinguish uniformly).

ii) Most quartz occurs as anhedral grains and subhedral crystals which range from ~0.2 mm up to ~1 mm long. They are randomly oriented. All display subradiating internal microstructure, and all are clouded by minute fluid inclusions concentrated in indistinct growth zones in each grain. The fluid inclusions are ragged in shape and turbid in appearance, but are too small for useful petrographic observations.

iii) A minor amount of quartz occurs as larger bladed grains up to ~2 mm long. They are concentrated in poorly-defined vughy sites, and terminations of these crystals project into remnant open space.

Hematite is moderately abundant, and two textural types are observed:

i) Most hematite occurs as well-shaped bladed crystals which range from ~20 μm up to ~2 mm long. They are distributed through much of the rock, but in places are loosely concentrated in indistinct patches intergrown with finer-grained quartz. Rare small pyrite crystals occur as inclusions within the larger hematite crystals.

ii) Minute hematite specks of submicron size are concentrated in small diffuse aggregates, and represent the red patches observed in the hand sample. This hematite occurs in the same areas as the larger hematite crystals of i) above.

Monazite is present in minor amount, forming small euhedral prisms ~50-200 μm in size, but some range up to ~400 μm. Most occurs as single crystals and aggregates of crystals, located within the quartz-hematite patches, but some also occurs in the hematite-poorer areas.

INTERPRETATION :

This sample is considered to have crystallised from silica-Fe-P-REE-bearing hydrothermal fluid under epithermal conditions. This produced the massive assemblage of quartz + hematite + monazite. Textures allow interpretation of paragenetic stages of mineral formation:

1. Quartz

Earliest quartz formed in minor amount as subhedral to euhedral blocky crystals.

2. Quartz + hematite + monazite ± trace pyrite

Much of the rock crystallised in this stage, which produced abundant quartz, lesser hematite (some with trace small pyrite inclusions), and minor monazite. The quartz displays a subradiating internal microstructure, and contains tiny turbid fluid inclusions.

3. Quartz

Minor quartz formed as the latest stage, producing larger subhedral grains with identical characteristics as quartz of stage 2. In places, these quartz grains project into vughs.

SAMPLE ID : 2065345 (Mt Gee Epithermal System, Arkaroola, SA)

STRATIGRAPHY : Mount Gee Sinter

LITHOLOGY : -

SECTION NO. : 2065345

HAND SPECIMEN : The rock sample represents a patchy black and white rock, composed of small to larger patches of metallic dark grey and reddish hematite, in translucent pale grey to white hard siliceous matrix. Poorly defined bladed quartz grains have grown outwards from the hematite-rich patches, projecting into minor small vughs.

The sample fails to respond to the hand magnet, suggesting magnetite is absent.

ROCK NAME : Quartz-hematite-monazite epithermal rock

PETROGRAPHY AND MINERAGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	Vol %	Origin
Quartz (fine-grained, subradiating)	44	Epithermal 1a
Hematite	15	Epithermal 1a
Monazite	<1	Epithermal 1a
Quartz (coarse-grained, subradiating)	40	Epithermal 1b

In polished thin section, this sample displays a massive inequigranular open space-filling texture.

Quartz dominates the rock, and two textural types are distinguished:

i) Much quartz occurs as small anhedral to subhedral grains which form massive small to large patches, ranging from a few millimetres up to one of centimetre size. The small quartz grains display weak internal subradiating texture, and minute fluid inclusions produce a slightly turbid appearance.

ii) A similar amount of quartz occurs as larger bladed grains mostly ~0.5-1.0 mm long. These grains have overgrown the earlier-formed finer-grained patches, and project inwards in subcrustiform texture. Local remnant vughs are present. This quartz contains fluid inclusions in clouds, concentrated in crystal growth faces; most are too small for useful petrographic observations, but some larger ones appear to be 2-phase type composed of a small darker vapour bubble (CO_2-bearing) in colourless liquid (H_2O-rich).

Hematite is moderately abundant. Most occurs as randomly oriented bladed crystals which range widely in size from ~0.2 mm up to ~2 mm long. They are located in small to larger patches with the finer-grained quartz. Minute hematite blades form local small aggregates, and are responsible for the reddish colour of patches in the hand sample.

Monazite occurs in minor amount as small euhedral crystals ~100-200 μm in size. Most occur within the single larger centimetre-sized patch of finer-grained quartz and hematite, but some also occur in the other smaller quartz-hematite patches.

INTERPRETATION :

This sample represents a quartz-hematite-monazite epithermal deposit with is inferred to have crystallised from silica-Fe-P-REE-bearing hydrothermal fluid. Paragenetic stages of crystallisation are inferred from the minerals and their textures:

1. Quartz + hematite + monazite

Early-formed quartz crystallised as small anhedral grains, accompanied by bladed hematite crystals and minor small monazite crystals.

2. Quartz

Late-formed quartz is coarser-grained, and locally projects into remnant open space (vughs). Small fluid inclusions are concentrated in crystal growth faces in the quartz, and similar but poorly-developed inclusions are also observed in the finer-grained early quartz.

SAMPLE ID : 2065346 (Mt Gee Epithermal System, Arkaroola, SA)

STRATIGRAPHY : Mount Gee Sinter

LITHOLOGY : -

SECTION NO. : 2065346

HAND SPECIMEN : The rock sample represents a massive rock composed of abundant fine-grained dark metallic grey hematite aggregates mostly several millimetres in size, in a white siliceous matrix. Fine-grained reddish hematite pervades the rock.

The sample fails to respond to the hand magnet, suggesting magnetite is absent.

ROCK NAME : Partly weathered, quartz-hematite-monazite epithermal rock

PETROGRAPHY AND MINERAGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	Vol %	Origin
Quartz (finer-grained, massive, subradiating)	57	Epithermal 1a
Hematite	20	Epithermal 1a
Monazite	Tr	Epithermal 1a
Quartz (coarser-grained, bladed, subradiating)	20	Epithermal 1b
Voids	2	Vughs (remnant open space 1)
Iron oxides (hematite, goethite)	Tr	Weathering 2

In polished thin section, this sample displays a massive inequigranular open space-filling epithermal texture, modified by weak oxidation effects.

Quartz is abundant, and two textural types are distinguished:

i) Much quartz occurs as small anhedral grains and small subhedral bladed grains mostly ~0.1-0.4 mm in size. They are concentrated in indistinct ragged patches with hematite. Tiny fluid inclusions form minor diffuse clouds.

ii) A lesser amount of quartz occurs as larger subhedral bladed grains ~0.4 mm long. They occupy indistinct areas between the finer-grained quartz-hematite patches, and in places the crystals project in subcrustiform texture into vughs (remnant open space). Tiny fluid inclusions lightly cloud the quartz grains but are too small for useful petrographic observations.

Hematite is present in moderate amount as small to larger bladed crystals ~20 µm to ~2 mm long. They occur as discrete crystals and also as intergrown aggregates of many crystals. In places, fine-grained reddish to opaque iron oxides (hematite, including goethite) are concentrated in and around the hematite aggregates, and in places appear to have severely replaced some hematite aggregates to produce a fine-grained massive turbid patch of iron oxides.

Monazite occurs in trace amount as small crystals and aggregates of crystals which range widely in size from tens of microns up to ~0.8 mm. They occur mostly within the finer-grained aggregates of quartz + hematite.

INTERPRETATION :

This sample is considered to have crystallised from silica-Fe-P-REE-bearing hydrothermal fluid in an epithermal environment, producing the assemblage of quartz + hematite + monazite. Mineral textures allow identification of paragenetic stages of crystallisation:

1. Quartz + hematite + monazite

Most of the rock crystallised to form a fine-grained massive intergrown assemblage of quartz, lesser hematite and minor monazite.

2. Quartz

A minor proportion of the rock crystallised as late-formed quartz, which was somewhat coarser-grained, bladed, with subradiating internal microtexture and minor tiny fluid inclusions. Minor vughs survived as small remnant cavities.

3. Goethite

At a later time, circulation of meteoric waters produced fine-grained hematite + goethite, in places partly destroying the earlier hematite patches.

SAMPLE ID : 2065347 (Mt Gee Epithermal System, Arkaroola, SA)

STRATIGRAPHY : -

LITHOLOGY : Brecciated granite

SECTION NO. : 2065347

HAND SPECIMEN : The rock sample represents a massive fine- to medium-grained felsic crystalline rock, composed of abundant pink feldspar and lesser translucent grey quartz grains. A latticework of dark (hematite-sealed) fractures is developed sparsely through the rock.

ROCK NAME : Fractured and hematite altered, K-feldspar-muscovite-?magnetite altered granitoid

PETROGRAPHY AND MINERAGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	Vol %	Origin
Quartz	35	Relict igneous 1
K-feldspar (microcline)	62	?Relict igneous 1 / ?alteration 2
Muscovite	<1	Alteration 2
Magnetite	Tr	Alteration ?2
Monazite	Tr	?Relict igneous 1 / ?alteration 2
Rutile	Tr	Alteration 2
Hematite	1	Alteration 3 / fracture seals 3

In polished thin section, this sample displays a massive allotriomorphic granitoid texture, modified by alteration effects in possibly two stages.

K-feldspar dominates the rock. It occurs as equant anhedral grains mostly ~0.2-1.0 mm in size. They are distributed throughout the rock, and tend to from a granular mosaic with no evident primary crystal faces. Uncommon larger grains up to several millimetres in size also are present. All of the K-feldspar displays the combined albite and pericline twinning ('tartan' twinning) typical of microcline. The K-feldspar likely represents K-feldspar-altered precursor granitoid feldspar grain sites.

Quartz is the other principal mineral. It forms anhedral equant grains ~0.2-2.0 mm in size, displaying ovoid shapes and tendency to form granular aggregates. Most grains display weak shadowy strain extinction. The size and shape of the quartz grains allows an igneous granitoid origin.

Muscovite is present in minor amount. It forms small to larger ragged plates that are sparsely scattered through the rock, and in places tend to be loosely concentrated in patches. It clearly is an alteration phase.

Magnetite may be present in trace amount as rare tiny equant crystals in K-feldspar and quartz. Most appear to be replaced by optically continuous hematite. Most hematite, in contrast, occurs as small bladed crystals, small fine-grained aggregates that are concentrated in fractures, and granulation zones irregularly developed through the rock. In these zones, nearby K-feldspar and quartz grains have suffered fragmentation to produce smaller grains of the same types.

Rutile is present in trace amount as anhedral small grains concentrated in local small aggregates.

Monazite is observed as small equant crystals, located uncommonly in quartz and in K-feldspar. It is uncertain whether they represent a relict igneous phase or an alteration phase.

INTERPRETATION :

This sample displays minerals and textures which are interpreted in the following sequence of events, from earliest to latest:

1. Intrusion of granitoid

A granitoid intrusion was emplaced in crustal rocks, and crystallised to form a massive medium-grained assemblage of feldspar + quartz + trace accessory minerals. The granitoid crystallised as a felsic rock, possibly strongly fractionated, because there is little evidence of primary ferromagnesian minerals.

2. Potassic alteration of granitoid

The primary granitoid suffered selective pervasive alteration of potassic type. This generated abundant microcline + minor muscovite + trace magnetite + rutile. The microcline may have formed mainly by inversion of primary orthoclase in a quartz syenitic protolith, or it may have formed by complete replacement of feldspar (possibly including plagioclase) in a less potassic granitoid. Minor magnetite formed as tiny blocky crystals sparsely scattered through the rock.

3. Fracturing and hematitic alteration of granitoid

The granitoid suffered brittle fracturing, producing poorly-defined micro-granulation zones through the rock. Infiltration by Fe-bearing fluid produced new alteration hematite along the fractures and in the microgranulation zones (darker in hand sample).

SAMPLE ID : 2065348 (Mt Gee Epithermal System, Arkaroola, SA)

STRATIGRAPHY : -

LITHOLOGY : Diamictite

SECTION NO. : 2065348

HAND SPECIMEN : The rock sample represents a massive (non-layered, non-structured), matrix-supported fragmental rock composed of minor scattered small to large clasts several millimetres to ~5 mm in size and composed of translucent grey quartz and feldspar, scattered sparsely through a fine-grained brick red matrix.

ROCK NAME : Sericite-hematite diamictite

PETROGRAPHY AND MINERAGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	Vol %	Origin
Quartz	56	Clastic grains 1
Lithics (quartz, sericite, K-feldspar, hematite)	10	Lithic clasts 1
K-feldspar (microcline)	1	Clastic grains 1
Hematite	<1	Clastic grains 1
Muscovite	Tr	Clastic grains 1
Tourmaline	Tr	Clastic grains 1
Zircon	Tr	Clastic grains 1
Sericite	30	Alteration 2 (after matrix 1)
Hematite	1	Alteration 2 (after matrix 1)

In polished thin section, this sample displays a massive, non-layered, non-sorted clastic sedimentary texture modified by recrystallisation of the matrix.

Clastic grains dominate the rock, and different types are recognised:

i) Crystal fragments are abundant, and quartz is dominant. It forms subangular to subrounded grains which range widely in size; many are ~0.4-0.8 mm in size, but they range down to tiny grains in the matrix. K-feldspar is uncommon, forming angular grains which display the characteristic combined albite and pericline twinning of microcline. Hematite forms angular grains. Muscovite occurs as colourless plates. Tourmaline forms uncommon subrounded grains pleochroic in drab green-brown colours. Zircon forms rare small angular grains with typical high relief, very pale pink colour and high birefringence.

ii) Lithic fragments are scattered irregularly through the rock. They are subangular in shape and range widely in size from ~0.4 mm up to ~1 cm. All appear to represent massive felsic crystalline rock (possibly granitoid) which are composed of anhedral quartz grains, anhedral microcline grains and aggregates, and fine-grained sericite-altered plagioclase grain sites. Some contain small hematite grains and clouds of grains.

Matrix encloses the clasts. Tiny angular clastic quartz grains lie in a fine-grained, poorly-crystallised sericite matrix through which are scattered tiny reddish hematite specks.

INTERPRETATION :

This sample is considered to have formed as a non-sorted, non-layered clastic sediment of diamictite type. It was composed of a minor proportion of lithic fragments in finer-grained matrix. The lithics appear to have formed as felsic crystalline rock of possible granitoid origin (quartz + plagioclase + K-feldspar), but was modified by severe selective pervasive sericite-hematite alteration prior to transport and deposition. Those larger clasts were deposited together with smaller sand- and silt-sized crystal fragments (quartz >> K-feldspar >> muscovite, hematite, tourmaline, zircon) in a fine-grained clay matrix with uniformly distributed hematitic material.

Subsequent modification of the rock involved mainly recrystallisation of the fine-grained clay-hematite matrix, producing fine-grained massive sericite + hematite. All of the ferruginous components are considered to have been in the rock prior to final lithification; this is consistent with the uniformly brick red colour of the matrix of the hand sample. The modification of the sediment occurred at quite low temperature.

SAMPLE ID : 2065349 (Mt Gee Epithermal System, Arkaroola, SA)

STRATIGRAPHY : -

LITHOLOGY : Diamictite

SECTION NO. : 2065349

HAND SPECIMEN : The rock sample represents a massive, non-layered clastic sediment composed of minor larger white, translucent grey and darker grey clasts up to several millimetres in size which are scattered through a finer-grained brick red matrix with sandy texture. Local small darker red patches are irregularly distributed.

ROCK NAME : Sericite-hematite diamictite

PETROGRAPHY AND MINERAGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	Vol %	Origin
Quartz	72	Clastic grains 1
Lithics (quartz, muscovite/sericite, K-feldspar, hematite, magnetite, rutile)	10	Clastic grains 1
Hematite (includes magnetite kernels)	<1	Clastic grains 1
K-feldspar (microcline)	Tr	Clastic grains 1
Rutile	Tr	Clastic grains 1
Magnetite	Tr	Clastic grains 1
Muscovite	Tr	Clastic grains 1
Zircon	Tr	Clastic grains 1
Sericite	15	Alteration 2 (after matrix 1)
Hematite	1	Alteration 2 (after matrix 1)

In polished thin section, this sample displays a non-sorted, non-layered clastic sedimentary texture, modified by alteration of matrix.

Clastic grains are abundant, and different types are distinguished:

i) Crystal fragments are abundant. Most are subangular but some are rounded. Quartz is abundant, forming clear grains which range widely in size from ~2 mm down to ~0.1 µm. Larger clasts are uncommon, and many clasts lie in the size ranges ~0.4 mm and ~0.1 mm. K-feldspar (microcline) forms smaller and larger angular clasts, displaying the ‘tartan’ twinning typical of this mineral. Hematite occurs as crystal fragments, some containing kernels of relict magnetite. Rutile forms angular grains which display their typical deep yellow colour in plane transmitted light. Magnetite occurs as uncommon grains with thin replacement margins of hematite. Muscovite forms colourless small to large plates. Zircon forms rare angular crystal fragments with pale pink colour.

ii) Lithic fragments occur in significant amount, and different types are recognised:

– Medium and coarse quartz sandstone with quartz-hematite altered matrix (hematite clearly was pre-depositional)

– Siltstone composed of abundant angular quartz clasts and minor muscovite clasts, in fine-grained sericite-altered matrix.

- Felsic crystalline (including ?gneissic) rocks, composed of granoblastic quartz, minor K-feldspar and indistinct bands of muscovite and magnetite partly replaced by hematite, and trace rutile.
- Micrographic intergrown K-feldspar + quartz, derived from igneous felsic crystalline rock
- Acid volcanic rock contains equant quartz phenocrysts in devitrified and albite-sericite-hematite altered groundmass.

Matrix of the rock is composed of tiny felsic grains (mainly quartz) in a matrix of fine-grained, poorly-crystallised sericite flakes. Hematite is sparsely distributed as minute reddish specks. In ragged patches many millimetres in size, the hematite is densely concentrated in the matrix and may mantle lithic fragments.

INTERPRETATION :

This sample formed by rapid deposition of lithic fragments and crystal fragments accompanied by fine-grained quartz-clay matrix. The rapid deposition is indicated by the non-sorted, non-layered characteristics of the sediment. Lithic and crystal fragments were derived from a wide range of source rocks, including hematite-altered gneissic felsic crystalline rocks (quartz, K-feldspar, sericite/muscovite, magnetite, hematite, rutile), sedimentary rocks (siltstones, sandstones, coarse sandstones variably sericite-hematite altered), and acid volcanic rocks (quartz-phyric, devitrified and sericite-hematite altered).

Post-depositional modification of the rock included partial recrystallisation of the matrix, producing fine-grained sericite + hematite which firmly cemented the rock. Local concentrations of dense very fine-grained hematite formed at this time (dark reddish small patches in the hand sample).

Note that different generations of hematite are inferred: pre-depositional hematite-sericite alteration of the variety of rocks, syn-deposition of hematite in the fine-grained clay matrix (brick red), and post-depositional hematite formation by low-grade matrix recrystallisation and localised concentration in small ragged patches.

SAMPLE ID : 2065350 (Mt Gee Epithermal System, Arkaroola, SA)

STRATIGRAPHY : -

LITHOLOGY : Diamictite

SECTION NO. : 2065350

HAND SPECIMEN : The rock sample represents a uniformly fine-grained clastic sediment that is drab yellow-brown in colour, with diffuse bands of darker grey.

ROCK NAME : Sericite-hematite feldspathic sandstone

PETROGRAPHY AND MINERAGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	**Vol %**	**Origin**
K-feldspar (microcline)	51	Clastic grains 1
Quartz	30	Clastic grains 1
Muscovite	5	Clastic grains 1
Hematite	<1	Clastic grains 1
Sericite	12	Recrystallisation 2 (after matrix 1)
Hematite	<1	Recrystallisation 2
Quartz	Tr	Veinlet seal 2
Sericite	Tr	Veinlet seal 2
Hematite	Tr	Veinlet seal 2

In polished thin section, this sample displays a non-layered, well-sorted, clast-supported sandy sedimentary texture, modified by grain suturing and matrix recrystallisation.

Clastic grains dominate the rock, and lie in sharp contact suggestive of grain boundary suturing. K-feldspar is abundant, forming angular crystal fragments displaying 'tartan' twinning. They are mostly ~0.1-0.2 mm in size (fine sand) but some range up to ~1.5 mm (very coarse sand). Quartz is less abundant, forming grains of similar size and displaying its lack of twinning and slightly higher birefringence (interference colours up to first order white in contrast with first order greys of K-feldspar). Muscovite occurs in moderate amount as colourless plates ~0.2-0.4 mm long; their weak preferred orientation defines sedimentary layering, not metamorphic foliation. Hematite occurs as angular grains sprinkled sparsely through the rock.

Matrix is composed of fine-grained white mica flakes (sericite) which thinly line the clastic grains or occupy small interstices between them. The mica is randomly oriented (ie no foliation). Minute reddish hematite specks are lightly sprinkled through the sericite, and also occur as sprinklings through the K-feldspar clastic grains.

A single thin veinlet is captured in the section. It is filled mostly by anhedral small clear quartz grains, accompanied by minor small sericite flakes and small hematite grains and aggregates.

INTERPRETATION :

This sample formed as a well-sorted clast-supported sandy clastic sediment composed of abundant crystal fragments (K-feldspar > quartz >> muscovite >> hematite) in minor fine-grained clay matrix. The dominance of microcline K-feldspar, quartz and muscovite as the clastic grains suggests that the principal source rocks were felsic crystalline rocks, and the presence of clastic hematite suggests that they were hematite-bearing.

At some time after deposition and burial, low-grade recrystallisation affected the rock, producing fine-grained non-foliated sericite + minor hematite after matrix. The presence of a single thin veinlet composed of quartz + sericite + hematite confirms that a small amount of fluid infiltrated the rock as part of this event.

SAMPLE ID : 2065351 (Mt Gee Epithermal System, Arkaroola, SA)

STRATIGRAPHY : -

LITHOLOGY : Diamictite

SECTION NO. : 2065351

HAND SPECIMEN : The rock sample represents a layered sediment composed of a brown layer and a paler yellow layer containing minor large pale pink hematite-stained clasts several millimetres in size.

ROCK NAME : Layered sediments:

Sandstone

Pebbly siltstone

PETROGRAPHY AND MINERAGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	Vol %	Origin
Feldspathic sandstone		
K-feldspar (microcline)	49	Clastic grains 1
Quartz	20	Clastic grains 1
Muscovite	10	Clastic grains 1
Sericite	20	Recrystallisation 2 (after matrix 1)
Hematite	1	Weathering 3
Pebbly siltstone		
Muscovite	29	Clastic grains 1
Lithics (quartz, K-feldspar, muscovite, hematite, rutile)	20	Lithic clasts 1
K-feldspar (microcline)	20	Clastic grains 1
Quartz	10	Clastic grains 1
Sericite	20	Recrystallisation 2 (after matrix 1)
Hematite	1	Weathering 3

In polished thin section, this sample displays similar mineralogies but different textures in two different layers.

Feldspathic sandstone represents the brownish layer observed in the hand sample. It displays a well-sorted, clast-supported clastic sedimentary texture in which grains ~100-200 µm in size (very fine sand to fine sand) are firmly sutured. K-feldspar is abundant, forming angular grains with indistinct twinning. Quartz is less abundant, and displays its clear appearance without twinning. Muscovite forms colourless plates ~200 µm long, with weak preferred orientation subparallel to the bedding plane between the two rock types.

Fine-grained matrix is composed of tiny poorly-formed white mica flakes (sericite/muscovite). Minor hematite occurs as very fine-grained dark red to opaque patches in local areas, and appears to be of weathering origin.

Pebbly siltstone represents the paler yellowish layer containing large clasts.

The large clasts are ~2-10 mm in size and display subrounded shapes. They represent altered felsic crystalline rocks of probable metamorphic origin, and are composed of moderately coarse-grained assemblages of anhedral quartz, angular anhedral K-feldspar grains (microcline), small flakes and larger plates of muscovite, and hematite as small grains and replacements of large equant ?magnetite crystals.

Matrix is dominated by clastic grains, mainly uniformly small muscovite flakes ~50-100 μm long aligned in the bedding plane. K-feldspar and lesser quartz form small angular grains. Very fine-grained sericite occupies the areas between the clasts, and appears to be of recrystallisation origin after clay matrix. Very fine-grained hematite of weathering origin forms diffuses patches in the matrix, and around the large lithic fragments.

INTERPRETATION :

This sample is considered to have initially formed as a layered sediment composed of sandstone and pebbly siltstone. The sandstone was composed of well-sorted crystal clasts (K-feldspar > quartz > muscovite) in a moderate amount of fine-grained clay matrix. The pebbly siltstone contained minor large lithic fragments (felsic crystalline metamorphic rock) in silty matrix composed of abundant crystal clasts (muscovite > K-feldspar > quartz) and a moderate amount of fine clay.

The fine clays of the matrix in the sediments recrystallised to form new fine-grained sericite. This is inferred to have occurred at P-T conditions of the lower greenschist facies. At a later time, partial oxidation generated new fine-grained hematite in irregularly distributed patches.

SAMPLE ID : **2065352 (Mt Gee Epithermal System, Arkaroola, SA)**

STRATIGRAPHY : -

LITHOLOGY : Diamictite

SECTION NO. : 2065352

HAND SPECIMEN : The rock sample captures the bedding plane contact between two different sediments: coarse-grained granule breccia containing pink hematite-stained feldspar in clasts, and fine-grained drab yellow silty sediment without large clasts.

ROCK NAME : **Layered sediments:**

Granule breccia

Siltstone

PETROGRAPHY AND MINERAGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	Vol %	Origin
Granule breccia		
Lithics (K-feldspar, quartz, muscovite, hematite, rutile)	65	Lithic clasts 1
K-feldspar	15	Clastic grains 1
Quartz	5	Clastic grains 1
Muscovite	5	Clastic grains 1
Sericite	10	Recrystallisation 2 (after matrix 1)
Siltstone		
K-feldspar (microcline)	43	Clastic grains 1
Muscovite	20	Clastic grains 1
Quartz	10	Clastic grains 1
Sericite	25	Recrystallisation 2 (after matrix 1)
Goethite/hematite	2	Weathering 3

In polished thin section, this sample displays different mineralogies and textures in two different sedimentary rock types.

Granule breccia is composed of abundant large angular lithic fragments ~2-6 mm in size, in a fine-grained silty matrix.

Lithics appear to be represented by two types:

i) Felsic crystalline rocks are composed of varied massive granular crystalline assemblages of clear anhedral quartz grains, tartan-twinned microcline grains, and small flakes and aggregates of sericite/muscovite locally after the feldspar grains. Large blocky grains of ?magnetite have been completely replaced by massive hematite.

ii) Uncommon smaller angular lithic fragments of micrographic K-feldspar (orthoclase) and quartz are identified, and are likely to have been derived from a massive felsic non-metamorphosed granitoid.

Fine-grained sandy matrix is massive in texture, composed of small randomly oriented clastic grains (K-feldspar, quartz, muscovite) ~0.2 mm in size (ie fine sand), in fine-grained sericite after precursor clay matrix.

Siltstone represents the fine-grained pale yellowish layer observed in the hand sample. Tiny crystal fragments of K-feldspar and quartz ~25 μm in size (clay to very fine silt) are abundant, and similarly small flakes of muscovite are randomly oriented. Very fine-grained sericite occupies the matrix, and is readily interpreted as recrystallised precursor clay.

Goethite/hematite occurs as turbid yellowish brown staining which locally pervades the rock, but elsewhere is absent. It appears to be of weathering origin.

INTERPRETATION :

This sample represents layered sediments of granule breccia and siltstone types. The granule breccia was composed of abundant large angular lithic fragments (sericite-hematite altered felsic crystalline rock >> micrographic granite) in a fine-grained sandy matrix (K-feldspar > quartz = muscovite) with additional fine-grained clays. The siltstone was composed of similar but smaller mineral grains as in the sandy matrix of the granule breccia, ie K-feldspar > muscovite > quartz, accompanied by fine-grained clays.

Recrystallisation of the sediments at low-grade conditions produced fine-grained sericite after the matrix clays. This, together with grain suturing, produced the massive competent sedimentary rocks.

SAMPLE ID : **2065353 (Mt Gee Epithermal System, Arkaroola, SA)**

STRATIGRAPHY : Mount Gee Sinter

LITHOLOGY : Fe staining at tips of laumontite

SECTION NO. : 2065353

HAND SPECIMEN : The rock sample represents a banded space-filling epithermal deposit, in which colloform bands are defined by translucent grey quartz, white quartz and dark brown stained quartz.

ROCK NAME : **Colloform banded quartz-hematite epithermal rock**

PETROGRAPHY AND MINERAGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	**Vol %**	**Origin**
Clay	5	Weathering 2 (after bladed crystal 1a)
Quartz (coarse, subradiating, crustiform)	22	Epithermal 1b
Quartz (bladed, subradiating, clouded)	20	Epithermal 1c
Hematite (acicular, clouds)	3	Epithermal 1c
Quartz (coarse, bladed, subradiating)	50	Epithermal 1d

In polished thin section, this sample displays a colloform banded to crustiform epithermal space-filling texture.

Overgrowth textures allow identification of the sequence of mineral formation (mineral parageneses):

i) Two large bladed crystals >1 cm long are captured. Both have been completely replaced by fine-grained dense randomly oriented clay flakes. The precursor crystal remains unidentified.

ii) Quartz formed large clear bladed crystals with subradiating texture, propagating outwards from the early-formed large bladed crystals.

iii) Finer-grained bladed quartz crystals with subradiating texture have overgrown the earlier quartz. Minute fluid inclusions <2 μm in size cloud the quartz, and render it turbid; they are too small for useful petrographic observations. Tiny acicular hematite crystals lace the quartz, adding to the turbidity of this quartz in thin section and producing a brownish colour in hand sample. With decrease in abundance of hematite, the smaller inclusion-rich quartz crystals produce an overgrowing band which is white in the hand sample.

iv) Minor small clear bladed quartz crystals overgrow the turbid quartz of iii) above, but quickly give way to much larger bladed subradiating quartz crystals >4 mm long. This quartz is quite clear (ie lacks fluid inclusions) and is translucent grey in the hand sample.

INTERPRETATION :

This sample crystallised from silica-Fe-bearing hydrothermal fluid, filling the open space in which it formed. Textures allow identification of he paragenetic stages of mineral formation:

1. Unknown bladed crystals

Centimetre-long bladed crystals formed in minor amount. They remain unidentified because they have been completely replaced by fine-grained clay of subsequent weathering origin. Calcite sometimes forms bladed crystals of this form in epithermal deposits.

2. Quartz

Large clear bladed quartz crystals with subradiating texture nucleated on, and grew outwards from, the large crystals of stage 1.

3. Quartz + hematite

Finer-grained bladed quartz grains with subradiating texture and abundant tiny fluid inclusions overgrew the quartz of stage 2. Tiny acicular hematite crystals grew as a lacework within this quartz, and are responsible for the dark brown colour of this band in the hand sample. This stage represents influx of a different batch of silica-Fe-bearing hydrothermal fluid, which produced a more complex mineral assemblage (quartz + hematite) and trapped tiny fluid inclusions in the quartz.

4. Quartz

A final stage of quartz growth produced small to large subradiating bladed crystals, overgrowing the earlier quartz-hematite band. No fluid inclusions are present, resulting in a translucent pale grey colour in hand sample.

SAMPLE ID : 2065354-A (Mt Gee Epithermal System, Arkaroola, SA)

STRATIGRAPHY : -

LITHOLOGY : Diamictite

SECTION NO. : 2065354-A

HAND SPECIMEN : The rock sample represents a non-layered clastic rock composed of minor scattered larger cream to grey lithic fragments ~2-4 mm in size, irregularly distributed through a fine-grained brownish yellow sandy matrix.

ROCK NAME : Weakly weathered sericite-hematite diamictite

PETROGRAPHY AND MINERAGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	Vol %	Origin
Quartz	47	Clastic grains 1
Lithics (quartz, K-feldspar, sericite, hematite, zircon, monazite)	10	Lithic clasts 1
K-feldspar (microcline)	10	Clastic grains 1
Muscovite	Tr	Clastic grains 1
Zircon	Tr	Clastic grains 1
Sericite	30	Recrystallisation 2 (after matrix 1)
Hematite	<1	Recrystallisation 2
Goethite	2	Weathering 3

In polished thin section, this sample displays a non-layered, non-sorted clastic sedimentary texture, modified by recrystallisation of fine-grained matrix.

Lithic fragments are present in minor amount, and different types are recognised:

i) One large clast of subrounded felsic crystalline rock represents a massive sericite-hematite altered granitoid, now composed of anhedral quartz grains, anhedral weakly sericite-altered orthoclase grains, and large dense aggregates of fine-grained sericite containing small ragged alteration monazite grains. Uncommon but relatively large equant euhedral zircon crystals appear to be of igneous origin.

ii) Minor smaller clasts represent meta-sedimentary rocks, including sericite-altered meta-quartz sandstone, and sericite altered foliated meta-siltstone.

iii) Minor small angular lithic clasts appear to represent meta-felsic crystalline rock composed of anhedral quartz, anhedral microcline grains, and muscovite aggregates.

Fine-grained matrix is composed of abundant small angular crystal fragments of quartz and K-feldspar (microcline) mostly ~0.2-0.4 mm in size (medium sand size) and smaller grains ~25 μm in size (very fine silt), in a matrix of fine-grained randomly oriented sericite flecks. The fine-grained sericite mat everywhere is lightly stained by pale yellow-brown iron oxide (goethite) of likely weathering origin. Rare angular zircon crystal fragments are identified.

INTERPRETATION :

This sample formed by rapid deposition of non-sorted clastic materials in a significant amount of clay matrix. The clasts were composed of minor larger clasts up to pebble size, comprising sericite-monazite altered granitoid, and smaller lithics of sericite-hematite altered felsic crystalline rock, and silty to sandy meta-sedimentary rocks. Together, the non-sorted and non-layered texture, with wide range of clast sizes in fine-grained clay matrix encourages use of the term “diamictite”.

At a later time, the rock suffered selective recrystallisation of the muddy matrix, forming new fine-grained sericite + trace hematite.

A weak pervasive stain of goethite formed in response to circulation of meteoric waters.

SAMPLE ID : 20653354-B (Mt Gee Epithermal System, Arkaroola, SA)

STRATIGRAPHY : -

LITHOLOGY : Diamictite

SECTION NO. : 2065354-B

HAND SPECIMEN : The rock sample represents a pebbly sediment composed of minor large rounded clastic grains ~2-5 mm in size (variably translucent grey, pale pink, and dark grey) in finer-grained massive drab yellow matrix.

ROCK NAME : Weakly weathered sericite diamictite

PETROGRAPHY AND MINERAGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	Vol %	Origin
Quartz	45	Clastic grains 1
Lithics (quartz, K-feldspar, sericite, rutile, monazite, zircon)	10	Lithic clasts 1
K-feldspar (microcline)	10	Clastic grains 1
Muscovite	Tr	Clastic grains 1
Sericite	34	Recrystallisation 2 (after matrix 1)
Goethite	1	Weathering 3

In polished thin section, this sample displays a non-sorted, non-layered clastic sedimentary texture, modified by weak recrystallisation of matrix and subsequent weak pervasive oxidation (weathering) effect.

Lithic fragments occur in minor abundance, and different types are recognised:

i) Some clasts (~1 mm up to ~1.2 cm; coarse sand to pebble size) represent sericite-monazite altered massive felsic granitoid, composed of anhedral quartz grains, anhedral optically continuous K-feldspar grains (orthoclase), and fine-grained sericite which occurs as thin trails in the K-feldspar and as larger dense aggregates elsewhere. Rutile forms small microgranular turbid aggregates in some of the sericite-rich patches, and these patches also contain euhedral zircon crystals, hence possibly represent completely altered primary ferromagnesian grain sites. Some sericite also occurs as fine-grained dense mats which contain small ragged monazite grains (moderately high relief, cleavages, moderate birefringence). Much of the sericite is lightly stained by pale yellow-brown goethite of oxidation (weathering) origin.

ii) Felsic crystalline rocks are composed of anhedral quartz grains, anhedral microcline grains, and small to larger flakes of sericite/muscovite. These appear to represent severely altered precursor ?gneissic rocks.

iii) Fine-grained meta-sedimentary lithic fragments are composed of fine-grained foliated assemblages of plagioclase, quartz and fine-grained sericite with weakly preserved precursor metamorphic foliation.

Matrix is dominated by larger and smaller subangular to subrounded quartz grains in two size ranges: many are ~0.2-0.4 mm (medium sand) but some range up to ~0.8 mm (coarse sand), and tiny grains in the matrix are ~100-200 µm in size (very fine sand to fine sand). K-feldspar (microcline) forms minor angular crystal fragments in the same size ranges, and displays its typical tartan twinning. Fine-grained sericite forms tiny randomly oriented flakes throughout the matrix, and is readily interpreted as recrystallised primary clays. Turbid yellow-brown goethite lightly pervades the sericitic matrix, and may be of weathering origin.

INTERPRETATION :

This sample formed by rapid deposition of non-sorted, non-layered clastic sediment composed of minor lithics (coarse sand to pebble-sized altered granitoid, altered felsic crystalline rock, fine-grained meta-sediments) in matrix with bimodal size range (coarse sand to fine sand quartz and K-feldspar, accompanied by a significant proportion of fine-grained clays). It is notable that two types of felsic crystalline rocks are recognised:

i) massive medium to coarse-grained non-metamorphosed granitoid which contained orthoclase as the K-feldspar, trace primary zircon, and fine-grained alteration sericite with similarly small ragged monazite grains;

ii) massive recrystallised felsic metamorphic rocks composed of quartz + K-feldspar (microcline) + muscovite/sericite.

Recrystallisation of the matrix of the rock at moderately low P-T conditions produced fine-grained massive sericite.

At a later time, circulation of a small amount of near-surface meteoric waters generated new goethite as a faint stain in the matrix (yellow-brown in hand sample).

SAMPLE ID : 2065356 (Mt Gee Epithermal System, Arkaroola, SA)

STRATIGRAPHY : -

LITHOLOGY : Diamictite, matrix of clast dominated

SECTION NO. : 2065356

HAND SPECIMEN : The rock sample represents a pebbly sediment composed of minor large centimetre-sized subrounded pink crystalline clasts in a fine-grained sandy drab yellowish matrix.

ROCK NAME : Weakly weathered, sericite diamictite

PETROGRAPHY AND MINERAGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	Vol %	Origin
Quartz	45	Clastic grains 1
Lithics (quartz, K-feldspar, sericite, hematite, rutile, zircon)	25	Lithic clasts 1
K-feldspar (microcline)	10	Clastic grains 1
Muscovite	Tr	Clastic grains 1
Sericite	20	Recrystallisation 2 (after matrix 1)

In polished thin section, this sample displays a non-sorted, non-layered clastic sedimentary texture, modified by low-grade partial recrystallisation and weak weathering effects.

Lithic fragments are large (~1-2 cm) and subrounded in shape. They represent massive medium-grained granitoid composed of clear anhedral quartz grains, anhedral large K-feldspar grains that are orthoclase partly inverted to very fine tartan-twinned microcline, and fine-grained sericite patches. Local patches of micrographically intergrown quartz and K-feldspar are evident. Some of the sericite patches may represent alteration of ferromagnesian grain sites, because they contain fine-grained rutile aggregates (after precursor primary Ti-mineral) and small to larger primary stumpy prismatic zircon crystals. Equant grains of hematite display blocky shapes of magnetite; hence magnetite probably was the precursor phase for these hematite grains.

Matrix contains abundant larger and smaller subrounded to angular crystal fragments of quartz and K-feldspar (microcline). Larger grains are mostly ~0.1-0.4 mm in size (fine- to medium-sand), but some range up to ~1.5 mm (very coarse sand); tiny angular crystal fragments ~25-50 μm in size (very fine silt) are distributed through a similarly fine-grained mat of sericite. A very fine pale yellow-brown stain of Fe-oxide stains the sericite.

INTERPRETATION :

This sample was deposited as a non-sorted, non-layered pebbly sandstone. It contained minor larger lithic clasts in a sandy to silty matrix. The larger lithic clasts were sericite-hematite altered felsic granitoid. The matrix was composed of coarse sandy clasts in fine-grained silt-clay matrix.

Recrystallisation of the matrix in response to low-grade regional effects produced new fine-grained massive sericite without foliation (ie no metamorphic structure).

SAMPLE ID : 2065357 (Mt Gee Epithermal System, Arkaroola, SA)

STRATIGRAPHY : -

LITHOLOGY : Diamictite

SECTION NO. : 2065357

HAND SPECIMEN : The rock sample represents a clastic sediment composed of minor larger pale pink and grey clasts ~2-3 mm in size, distributed without layering through a finer-grained clastic matrix.

ROCK NAME : Sericite diamictite

PETROGRAPHY AND MINERAGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	Vol %	Origin
Quartz	59	Clastic grains 1
Lithics (quartz, K-feldspar, muscovite/sericite, rutile)	5	Lithic clasts 1
K-feldspar (microcline)	5	Clastic grains 1
Muscovite	Tr	Clastic grains 1
Tourmaline	Tr	Clastic grains 1
Sericite	30	Recrystallisation 2 (after matrix 1)
Goethite	<1	Weathering 3

In polished thin section, this sample displays a non-layered clastic sedimentary texture, modified by recrystallisation of matrix.

Lithic fragments occur in minor amount, and different types are recognised:

i) Felsic crystalline rock forms small to larger clasts ~1-5 mm in size, composed of massive assemblages of quartz, K-feldspar (microcline), muscovite and rutile. No primary textures are evident, so their origin remains uncertain.

ii) Meta-sedimentary rocks of silty origin form small angular platy clasts up to several millimetres in size. They are composed of varied abundances of fine-grained quartz and sericite/muscovite.

Crystal fragments are abundant. Quartz forms subangular to subrounded grains mostly ~0.1-0.2 mm in size (fine sand) but some range up to ~0.5-1.5 mm (coarse to very coarse sand). In the matrix, tiny angular grains ~25-50 μm are distributed uniformly through the matrix. K-feldspar occurs as crystal fragments of similar size and shape to quartz; uncommon very large grains of microcline ~2 mm in size are locally observed. Muscovite forms minor colourless plates. Tourmaline forms uncommon angular crystal fragments that are pleochroic from green to colourless.

Sericite occurs in significant amount as tiny randomly oriented flakes, which form a fine-grained matrix throughout the rock. In diffuse patches many millimetres in size, the sericite is stained by yellow-brown hydrated iron oxide (goethite) most likely of weathering origin.

INTERPRETATION :

This sample was deposited rapidly as a non-layered, poorly sorted clastic sediment composed of larger clasts in a fine-grained matrix. The larger clasts were of sand to coarse sand size, and included abundant sand-sized crystal fragments (quartz >> K-feldspar >> muscovite, tourmaline) and minor larger coarse sand sized lithic fragments (felsic crystalline rock, meta-sediments), in a fine-grained matrix of clays and tiny crystal fragments.

Subsequent recrystallisation of matrix clays at low P-T conditions produced fine-grained sericite without foliation.

At a much later time, circulation of near-surface meteoric waters produced a small amount of goethite as local diffuse oxidation patches.

SAMPLE ID : 2065358-A (Mt Gee Epithermal System, Arkaroola, SA)

STRATIGRAPHY : -

LITHOLOGY : Diamictite

SECTION NO. : 2065358-A

HAND SPECIMEN : The rock sample represents a brick red clastic sediment composed of minor larger cream and grey lithic fragments ~1-5 mm in size, sparsely and irregularly distributed through a brick red fine-grained matrix. In places there are paler amoeboid patches many millimetres in size distributed through the matrix.

ROCK NAME : Hematite stained (oxidised) sericite diamictite

PETROGRAPHY AND MINERAGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	Vol %	Origin
Quartz	71	Clastic grains 1
K-feldspar (microcline)	5	Clastic grains 1
Lithics (quartz, sericite/muscovite, K-feldspar hematite, rutile)	3	Lithic clasts 1
Muscovite	Tr	Clastic grains 1
Hematite (includes trace magnetite)	Tr	Clastic grains 1
Sericite	15	Recrystallisation 2 (after matrix 1)
Hematite	5 (Tr-5)	Weathering 3

In polished thin section, this sample displays a non-layered clastic sedimentary texture, modified by recrystallisation of matrix and subsequent pervasive oxidation effects.

Lithic fragments occur in minor amount. They are ~1-6 mm in size and display angular to rounded shapes. Different types are recognised:

i) Felsic crystalline rocks are composed of a massive assemblage of anhedral quartz grains, small to large anhedral K-feldspar grains (microcline), small to large flakes of sericite/muscovite, and minor small rutile grains.

ii) Meta-sedimentary rocks are represented by meta-siltstones in which primary clastic grains of quartz and muscovite are firmly sutured, and fine-grained alteration sericite forms scattered matrix.

iii) Acid volcanic fragments retain some of their porphyritic igneous textures, where large phenocrysts of K-feldspar and smaller quartz crystals lie in a devitrified groundmass of quartz, K-feldspar and sericite.

Crystal fragments are abundant. Quartz forms subangular to rounded grains mostly ~0.1-0.4 mm in size, but some range up to ~0.8 mm. K-feldspar (microcline) forms minor angular crystal fragments of similar size range. Muscovite occurs as uncommon colourless plates. Hematite forms uncommon angular grains, but some equant blocky crystals retain kernels of magnetite which confirms some of the hematite originally formed as magnetite.

Fine-grained matrix contains tiny angular quartz grains ~25-50 μm in size in a mat of randomly oriented tiny sericite flecks. In some areas, hematite occurs only in trace amount as tiny reddish specks and small aggregates, but in most of the rock the matrix is pervaded by moderately abundant fine-grained hematite.

INTERPRETATION :

This sample was initially deposited as a non-layered coarse sandy sediment composed of a minor proportion of larger lithic fragments (felsic crystalline rocks, acid porphyritic igneous rocks, meta-silty sedimentary rocks) in a matrix of sandy clastic particles (quartz >> K-feldspar >> muscovite > hematite/magnetite) and clay.

Recrystallisation of matrix of the sediment occurred at moderately low P-T conditions, producing a fine-grained matrix of sericite after the primary clay.

At a later time, the rock was infiltrated by near-surface meteoric waters which produced fine-grained hematite pervasively through the matrix. In places, little or no hematite was deposited where the meteoric waters failed to access the rock in any significant amount. These areas are paler in the hand sample.

SAMPLE ID : 2065358-B (Mt Gee Epithermal System, Arkaroola, SA)

STRATIGRAPHY : -

LITHOLOGY : Diamictite

SECTION NO. : 2065358-B

HAND SPECIMEN : The rock sample represents a non-layered fragmental rock composed of minor larger rounded to angular lithic clasts of different colours (cream, grey), irregularly distributed through a brick red matrix.

ROCK NAME : Hematite stained (oxidised) sericite diamictite

PETROGRAPHY AND MINERAGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	**Vol %**	**Origin**
Quartz	64	Clastic grains 1
Lithics (quartz, sericite/muscovite, K-feldspar)	10	Lithic clasts 1
K-feldspar (microcline)	2	Clastic grains 1
Muscovite	Tr	Clastic grains 1
Hematite (including magnetite kernels)	<1	Clastic grains 1
Sericite	20	Recrystallisation 2 (after matrix 1)
Hematite	3 (Tr-10)	Weathering 3

In polished thin section, this sample displays a non-layered clastic sedimentary texture, modified by matrix recrystallisation and subsequent selective oxidation.

Lithic fragments occur in moderate amount., and different types are recognised:

i) Felsic crystalline rock forms subangular to subrounded clasts up to ~6 mm in size. They are composed of a medium-grained massive to weakly foliated granoblastic metamorphic assemblage of anhedral quartz, anhedral tartan-twinned microcline grains, muscovite flakes, and patches of fine-grained massive alteration sericite.

ii) Felsic granitoid also forms large clasts, displaying a massive felsic granitoid texture with some micrographic patches of intergrown quartz and K-feldspar (optically continuous orthoclase), and uncommon small equant zircon crystals.

iii) Silty clastic sedimentary rocks are composed of small angular quartz clasts and minor muscovite clasts in fine-grained sericitic matrix. One clast may have contained moderately abundant ?biotite but this has been stained and altered by oxidation products; in this clast, relict blocky crystals of magnetite display severe replacement by hematite.

Crystal fragments are abundant. Quartz forms subangular to subrounded grains mostly ~0.1-0.4 mm in size, but some range up to ~1 mm. K-feldspar (microcline) grains are much less common, and are similar in size. Muscovite forms trace small colourless flakes. Hematite occurs in minor amount as small angular grains; some are more blocky in shape and contain relict magnetite kernels, confirming that hematite-altered magnetite formed part of the clastic assemblage.

Matrix is composed mostly of tiny randomly oriented sericite flecks, which form a fine-grained mat enclosing the clasts. Tiny angular quartz grains tens of microns in size are distributed through the sericite mat.

Hematite occurs as cryptocrystalline red specks and clouds which pervade the rock in varied abundance. In some areas it is absent, but in other areas it is more densely concentrated particularly in the matrix.

INTERPRETATION :

This sample was deposited as a non-layered, poorly-sorted clastic sediment composed of minor coarse sand to granule sized lithic fragments in a sandy to silty matrix. The larger lithic fragments included metamorphic felsic crystalline rocks, meta-silty sedimentary rocks, and non-metamorphosed felsic granitoid containing micrographic patches. Much of the clastic material was sandy in grain size, dominated by quartz but also including minor K-feldspar and muscovite (likely from the metamorphic felsic crystalline rocks) and hematite (some with relict magnetite kernels). These clastic components were deposited in fine-grained clays and tiny clastic quartz particles.

The fine-grained matrix recrystallised in response to mildly elevated P-T conditions, producing fine-grained sericite which firmly binds the rock.

At a later time, circulation of near-surface meteoric waters generated new fine-grained hematite as a stain in the more permeable matrix. Patchy distribution of the hematite indicates that the meteoric waters infiltrated the rock irregularly.

SAMPLE ID : 2065360-A (Mt Gee Epithermal System, Arkaroola, SA)

STRATIGRAPHY : -

LITHOLOGY : Diamictite

SECTION NO. : 2065360-A

HAND SPECIMEN : The rock sample represents a fragmental rock composed of minor scattered larger clasts several millimetres in size but one dull brown clast is of centimetre size, in a fine-grained drab yellow-brown matrix locally pervaded by dark red-black iron oxide products.

ROCK NAME : Hematite stained (oxidised) pebbly sericite diamictite

PETROGRAPHY AND MINERAGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	Vol %	Origin
Quartz	57	Clastic grains 1
Lithics (quartz, muscovite/sericite, K-feldspar, biotite, rutile, zircon)	15	Lithic clasts 1
K-feldspar (microcline)	3	Clastic grains 1
Muscovite	Tr	Clastic grains 1
Rutile	Tr	Clastic grains 1
Biotite	Tr	Clastic grains 1
Zircon	Tr	Clastic grains 1
Sericite	20	Recrystallisation 2 (after matrix 1)
Quartz	Tr	Fracture seal 2
Carbonate (calcite)	Tr	Fracture seal 2
Hematite	3 (0-10)	Weathering 3

In polished thin section, this sample displays a non-layered, non-sorted clastic sedimentary texture, modified by matrix recrystallisation and selective oxidation overprint.

Lithic fragments occur in minor amount, and different types are recognised:

i) Felsic crystalline rock fragments are subangular to subrounded in shape, and range >6 mm in size in the thin section, and possibly >1 cm in the hand sample. They display massive to weakly foliated granoblastic metamorphic assemblages of varied abundances of clear anhedral quartz grains (some with tiny biotite inclusions), muscovite flakes, K-feldspar grains (microcline), minor small rutile granules and aggregates, and rare zircon grains of probable relict clastic origin. These are interpreted as medium-grade meta-sediments derived from sandy to silty protoliths.

ii) Sericite-altered micrographic granite fragments ~2-4 mm in size are composed of intergrown quartz and K-feldspar, the latter replaced by fine-grained sericite.

iii) Uncommon acid volcanic rock fragments <2 mm in size are composed of a fine-grained mosaic of tiny anhedral K-feldspar grains and lesser quartz, with faintly preserved primary fluidal structure of possible tuffaceous origin.

Matrix is dominated by crystal fragments of different types: abundant subangular to subrounded quartz grains ~0.1-0.4 mm in size but some range up to ~0.8 mm; minor K-feldspar (microcline) grains of similar size and shape; other uncommon crystal fragments include trace colourless muscovite flakes, small granules and aggregates of rutile, rare small biotite plates displaying typical pleochroism from tan brown to pale yellow (ie normal Fe-Mg biotite composition), and rare small zircon fragments. Fine-grained randomly oriented sericite flakes enclose the clastic particles, and are accompanied by tiny angular quartz crystal fragments ~25-50 μm in size.

Oxidation has produced fine-grained dark reddish hematite which pervades the matrix in large areas of the rock (dark red to black in hand sample), and it is absent from other large areas (paler drab yellow-brown in hand sample).

INTERPRETATION :

This sample was initially deposited as a pebbly sandstone (diamictite) composed of minor larger lithic fragments in sandy to silty matrix. The lithic fragments included felsic metamorphic crystalline rocks of meta-sedimentary origin, sericite-altered massive micrographic granite, and acid volcanogenic rocks. The sandy to silty component included quartz, K-feldspar, and trace others (muscovite, rutile, biotite, zircon) in a fine-grained clay matrix.

Recrystallisation of the clay matrix produced fine-grained sericite which firmly binds the rock. This is inferred to have occurred at relatively low P-T conditions.

At a later time, the rock was infiltrated by oxidised meteoric waters, which produced a dark brown to black hematite stain pervasively through the matrix in large volumes of he rock. The oxidised waters failed to access other parts of the rock, leaving them with a paler drab yellow-brown appearance in the hand sample.

SAMPLE ID : 2065360-B (Mt Gee Epithermal System, Arkaroola, SA)

STRATIGRAPHY : -

LITHOLOGY : Diamictite

SECTION NO. : 2065360-B

HAND SPECIMEN : The rock sample represents a pebbly sediment composed of minor large lithic fragments in a fine-grained oxidised matrix mostly dark red-brown in colour but with local large (centimetre-sized) non-oxidised ovoids of paler yellow-brown rock.

ROCK NAME : Partly oxidised, pebbly sericite diamictite

PETROGRAPHY AND MINERAGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	Vol %	Origin
Quartz	63	Clastic grains 1
Lithics (quartz, muscovite/sericite, K-feldspar, rutile, biotite)	10	Lithic clasts 1
K-feldspar (microcline)	2	Clastic grains 1
Muscovite	Tr	Clastic grains 1
Zircon	Tr	Clastic grains 1
Sericite	20	Recrystallisation 2 (after matrix 1)
Hematite	4 (0-5)	Weathering 3

In polished thin section, this sample displays a non-layered clastic sedimentary texture, modified by recrystallisation of fine-grained matrix and subsequent partial oxidation.

Lithic fragments occur in minor amount, and different types are recognised:

i) Felsic crystalline rock fragments with subrounded shape up to ~8 mm in size are composed of varied abundances of quartz, muscovite, minor biotite, and rutile. They appear to represent medium-grained metamorphic rocks of sandy sedimentary origin.

ii) Low-grade silty metasedimentary rock fragments with subrounded shape many millimetres in size retain their primary clastic sedimentary texture define by clastic quartz grains and aligned clastic flakes of muscovite and biotite, in fine-grained recrystallised sericite/muscovite matrix. Other meta-sedimentary rock fragments are smaller and appear to represent meta-silty to shaly sediments.

iii) Micrographic granitoid forms uncommon subrounded fragments which retain their micrographic primary texture but feldspar has been severely replaced by fine-grained sericite.

iv) Deformed meta-acid volcanic rock contains large K-feldspar crystals (orthoclase) aligned in a recrystallised matrix of fine-grained K-feldspar, quartz, and minor small magnetite crystals replaced by hematite.

Matrix is dominated by subangular to subrounded crystal fragments, mostly quartz which forms grains ~0.1-0.8 mm in size. K-feldspar (microcline) forms minor fragments of similar size, displaying its typical tartan twinning. Muscovite occurs as small colourless flakes. Zircon forms uncommon small crystal fragments with typical high relief and high birefringence. Fine-grained sericite forms tiny randomly oriented flecks which occupy the matrix between the clastic grains, and also encloses tiny fragments of quartz ~25-50 μm in size.

Fine-grained dark red hematite pervades the sericitic matrix in large areas of the rock, but is absent from other large areas (pale yellow-brown ovoid patches in hand sample).

INTERPRETATION :

This sample initially formed as a non-sorted pebbly sandstone (diamictite) composed of minor lithic fragments in a mostly sandy matrix with additional fine-grained silt and clay materials. The lithic fragments included meta-sedimentary rocks of medium metamorphic grade (quartz, muscovite, biotite), meta-sedimentary rocks of lower metamorphic grade, sericite-altered micrographic granitoid, and deformed acid volcanic rock. The presence of biotite in the metamorphic assemblage of the meta-sedimentary rocks confirms that P-T metamorphic conditions reached at least into the middle greenschist facies. Note the absence of metamorphism from the altered micrographic granitoid.

Modification occurred at relatively low P-T conditions, causing recrystallisation of the matrix clays to produce a fine-grained sericite mat which firmly binds the competent rock.

At a later time, circulation of near-surface meteoric waters generated new fine-grained hematite staining in the matrix areas, generating a pervasive dull red-brown colour through rock. Ovoid centimetre-sized paler yellow-brown patches observed in the hand sample represent preserved kernels of the host rock where the oxidising meteoric waters failed to infiltrate the rock.

SAMPLE ID : 2065362-A (Mt Gee Epithermal System, Arkaroola, SA)

STRATIGRAPHY : Mount Gee Sinter

LITHOLOGY : -

SECTION NO. : 2065362-A

HAND SPECIMEN : The rock sample represents a banded rock composed of translucent grey bands and yellow to red bands stained by iron oxides. Indistinct colloform texture is evident in some of the bands, and local small vughs are observed. An aggregate of intergrown thin bladed hematite crystals is observed in quartz at one end of the sample, but was not captured in the section.

ROCK NAME : Partly oxidised, colloform banded quartz-hematite epithermal rock

PETROGRAPHY AND MINERAGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	**Vol %**	**Origin**
Quartz (fine-grained, massive, microcrystalline)	20	Epithermal 1a
Hematite (bladed to blocky)	Tr (0-Tr)	Epithermal 1a
Quartz (coarse-grained, subradiating, crustiform)	55	Epithermal 1b
Quartz (gel textured, with trace hematite)	20	Epithermal 1c
Iron oxides (goethite)	5	Weathering 2

In polished thin section, this sample displays a colloform banded epithermal texture, modified by selective oxidation (weathering) effects.

Quartz dominates the rock. Textures allow identification of different parageneses (timing of formation) of quartz:

i) Earliest quartz displays a fine-grained massive microcrystalline texture. Tiny quartz grains ~0.1 mm in size form a massive mosaic. Most of this quartz is anhedral and equant in shape, but some grains display a weakly bladed shape. This quartz is concentrated in large patches with non-planar, wavy shapes.

ii) Coarse-grained quartz with bladed subradiating structure has overgrown the quartz of i) above, oriented outwards (away from) the earlier quartz. The subradiating blades are mostly ~1-2 mm long, and in places project in crustiform texture into remnant open spaces (vughs) ~4-6 mm in size. Although coarse-grained, the quartz appears to lack fluid inclusions and therefore is quite clear (translucent grey in hand sample).

iii) Fine-grained late-formed quartz is concentrated in bands ~5-10 mm thick. The quartz forms tiny uniformly sized ovoid grains ~50-100 μm in size. They are closely associated, and in places are grouped into aggregates. Some are optically continuous single grains, but others display a cruciform radiating texture. All of these grains contain thin outer growth zones defined by light concentrations of minute (micron-size) red specks likely to be hematite. Fine-grained quartz occupies a microcrystalline sutured mosaic between the ovoid grains.

Hematite occurs in significant amount in the early fine-grained quartz of i) above. It forms tiny acicular crystals and small equant crystals. Some of these appear to have been modified by later oxidation effects.

Iron oxides range widely in abundance through the rock. It is most abundant in the late-formed gel-like bands of quartz, where it forms tiny dark red diffuse aggregates in the interstitial microcrystalline quartz, not the ovoid quartz grains. Some iron oxides form dense linings of some of the vughs.

INTERPRETATION :

This sample crystallised from silica-Fe-bearing hydrothermal fluids at epithermal P-T conditions. The textures allow identification of mineral parageneses (mineral assemblages which formed with time):

1. Quartz + trace crystalline hematite

Fine-grained massive microcrystalline quartz with or without minor small hematite blades crystallised as the earliest stage.

2. Quartz

Coarse-grained subradiating quartz formed alone, in places projecting with crustiform texture into vughs.

3. Quartz + trace hematite cloud

Fine-grained quartz with gel-like texture crystallised as the final stage. Small ovoid quartz grains, in places with cruciform texture, crystallised with thin outer growth zones containing minute hematite specks. These were enclosed by finer-grained microcrystalline quartz.

At a later time, circulation of near-surface meteoric waters generated new poorly-crystallised hydrated iron oxide (goethite). This formed in different sites in the rock: densely in the matrix of the late gel-like bands, as selective replacements of the hematite crystals, and as fine-grained linings of some vughs.

SAMPLE ID : 2065362-B (Mt Gee Epithermal System, Arkaroola, SA)

STRATIGRAPHY : Mount Gee Sinter

LITHOLOGY : -

SECTION NO. : 2065362-B

HAND SPECIMEN : The rock sample displays pale grey and reddish brown banding on the millimetre to centimetre scale. Bands display translucent grey, yellowish cream, and brick red colours. Some bands display internal fine colloform texture, but other bands contain more tortuous internal banding defined by brick red patches in grey host.

ROCK NAME : Partly oxidised, colloform banded quartz-hematite epithermal rock

PETROGRAPHY AND MINERAGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	**Vol %**	**Origin**
Quartz (massive, microcrystalline)	5	Epithermal 1a
Quartz (coarse, bladed, subradiating)	25	Epithermal 1b
Quartz (gel-like, with trace hematite zoning)	58	Epithermal 1c
Quartz (coarse, massive, granular)	10	Epithermal 1d
Goethite	2 (0-10)	Weathering 2

In polished thin section, this sample displays a colloform banded epithermal texture, modified by selective staining by oxidation effects.

Quartz dominates the rock, and different textures and their relationships allow identification of stages of crystallisation (mineral parageneses):

i) Quartz occurs in minor amount as fine-grained massive microcrystalline aggregates with grain size <0.1 mm. These patches occupy central trails or discontinuous bands or patches, on which subsequent bands have grown.

ii) A significant amount of quartz occurs as relatively large, subradiating clear grains which overgrow the quartz of i) above. The quartz is quite clear, and appears to lack fluid inclusions (see translucent grey appearance in hand sample). The outermost margin of these bands are colloform (bulbous) in shape, and are overgrown by iii) below.

iii) Fine-grained quartz dominates this thick band. Much quartz occurs as tiny ovoid grains uniformly ~50 µm in size, some of which are coalesced into aggregates of ovoids. The ovoids are uniformly distributed, and all contain a thin outer zone defined by densely concentrated minute red hematite specks of submicron size. The presence of the hematite is responsible for the uniformly brick red colour of this band in the hand sample. The ovoids lie in a massive fine-grained microcrystalline quartz mosaic. Together, the uniform size of the tiny quartz ovoids and their coalesced form suggests a gel-like precursor.

iv) Late coarse-grained quartz forms anhedral clear grains ~1-2 mm in size, defining a massive granular texture.

Goethite occurs in moderate amount in the gel-like bands, where it forms a diffuse yellow-brown overprinting stain.

INTERPRETATION :

This sample displays minerals and textures which indicate it crystallised from successive pulses of hydrothermal fluid under epithermal P-T conditions. Space-filling colloform banded textures are developed with mineral parageneses as follows:

i) Earliest quartz formed in small patches and discontinuous trails with fine-grained microgranular massive texture.

ii) Coarser-grained subradiating quartz formed as thicker bands, projecting bulbous colloform outer margins towards the next assemblage.

iii) Fine-grained gel-like quartz crystallised as small coalesced ovoids with thin hematitic outer zones, in a fine-grained microcrystalline quartz cement. The presence of the hematite growth zones in the ovoid quartz grains suggests that this fluid was silica-Fe-bearing, in contrast with the silica-only precipitates from the other zones.

iv) Late-formed massive granular quartz filled the remaining parts of the rock.

At a later time, circulation of near-surface meteoric waters through the rock produced new cryptocrystalline goethite stains, mainly in the fine-grained quartz-hematite band.

SAMPLE ID : 2065364 (Mt Gee Epithermal System, Arkaroola, SA)

STRATIGRAPHY : Mount Gee Sinter

LITHOLOGY : -

SECTION NO. : 2065364

HAND SPECIMEN : The rock sample represents a uniformly fine-grained pale grey rock with indistinct lamination. Very fine-grained yellow-brown ferruginous staining of weathering origin pervades bands through the rock.

ROCK NAME : Weakly oxidised, weakly laminated quartz-hematite epithermal rock

PETROGRAPHY AND MINERAGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	**Vol %**	**Origin**
Quartz (very fine-grained, massive)	97	Epithermal 1a
Hematite (bladed)	Tr	Epithermal 1a
Quartz (fine-grained, crustiform)	2	Epithermal 1b
Goethite	<1 (0-1)	Weathering 2
?Jarosite	Tr	Weathering 2 (after ?pyrite 1a)

In polished thin section, this sample displays a fine-grained epithermal texture with indistinct banding and local crustiform vughs, overprinted by weak oxidation effects.

Quartz dominates the rock, and two textural types are recognised:

i) Most quartz occurs as minute anhedral grains ~5-20 μm in size. Together they form an equigranular massive mosaic throughout most of the rock. Indistinct banding is defined in this quartz.

ii) A minor amount of quartz occurs as small anhedral grains ~50-100 μm in size. They are concentrated in small patches and around vughs, and preferred orientation of these quartz concentrations defines indistinct banding.

Hematite occurs in trace amount as small bladed crystals in the coarser-grained patches, but mostly it is absent.

Goethite is present in minor amount as diffuse yellow-brown staining. Most occurs in the very fine-grained massive quartz. Some goethite appears to have modified the small hematite crystals, producing a finer-grained turbid indistinct replacement mat.

Possible ?jarosite occurs in trace amount as tiny yellow grains concentrated in dense aggregates pseudomorphous after some blocky crystal sites. The cubic forms of some of these sites suggests it may have been sulfide (eg ?pyrite).

INTERPRETATION :

This sample crystallised from silica-Fe(-?S)-bearing hydrothermal fluid at epithermal P-T conditions in open space. This produced a very fine-grained massive to weakly banded assemblage of quartz + trace others (hematite, ?pyrite). Most of the rock formed as very fine-grained massive microcrystalline quartz with indistinct banding. Minor late-formed quartz formed slightly coarser-grained aggregates in places around vughs. Minor other minerals (hematite, ?pyrite) formed in this late-formed quartz.

At a later time, circulation of near-surface meteoric water through the rock generated minor new goethite ± ?jarosite, mainly as diffuse staining in the very fine-grained massive quartz but also as replacements of precursor hematite and ?pyrite.

SAMPLE ID : 2065365 (Mt Gee Epithermal System, Arkaroola, SA)

STRATIGRAPHY : Mount Gee Sinter

LITHOLOGY : -

SECTION NO. : 2065365

HAND SPECIMEN : The rock sample represents a massive fine-grained pale yellow-brown rock which contains small (millimetre-sized) ragged pale translucent grey patches.

ROCK NAME : Weakly oxidised, quartz-?sulfide epithermal rock

PETROGRAPHY AND MINERAGRAPHY :

A visual estimate of the modal mineral abundances gives the following:

Mineral	Vol %	Origin
Quartz (very fine-grained, massive, microcrystalline, ferruginous staining)	73	Epithermal 1a
Quartz (fine-grained, subcrustiform)	25	Epithermal 1b
Opaques (?pyrite)	<1	Epithermal 1a, 1b
Goethite	<1	Oxidation 2

In polished thin section, this sample displays a massive, fine-grained, patchy epithermal texture with small vughs.

Quartz dominates the rock, and two types are distinguished:

i) Much quartz occurs as tiny anhedral grains mostly ~50 μm in size. They form a massive microcrystalline mosaic throughout most of the rock. All of this quartz is lightly pervaded by yellow-orange ferruginous staining; no grains are evident, just a uniform pervasive stain.

ii) A moderate amount of quartz occurs as small anhedral grains that range from ~50 μm up to ~100 μm. This quartz forms large ovoid or lobate patches of millimetre size distributed through the finer-grained quartz of i) above. The larger grains locally project into small vughs. These quartz patches are notably clear, in strong contrast with the yellow stained quartz of i) above.

Opaques occurred in minor amount as small cubic crystals, and some with a more bladed form. They occur in both the very fine-grained quartz with yellow stain, and also in the colourless quartz patches. Their cubic forms suggest that it was pyrite, but all have suffered complete oxidation to produce small voids or replacements by goethite.

INTERPRETATION :

This sample is considered to have crystallised from silica-Fe(-?S)-bearing hydrothermal fluid at epithermal P-T conditions. Very fine-grained quartz crystallised to form most of the deposit, with minor later-formed quartz that is slightly coarser grained and projects into small vughs. A minor amount of ?pyrite formed in the early and later quartz.

At a later time, meteoric waters percolated through the rock, producing new goethite as pervasive staining of some of the quartz, and as replacements of the ?pyrite crystals.

4 COMPARISON OF SAMPLE GROUPS

SAMPLES 2065334-A and -B:
Sections A and B of this sample display the same mineralogy (quartz + hematite + monazite) with similar textures and similar mineral parageneses. Both samples display colloform banding, with similar mineral parageneses from earliest to latest. Specular hematite and monazite formed only in the earliest paragenesis. Specular hematite is better-formed and more abundant in sample A, and in that sample is also concentrated in a thin band. Monazite also is more abundant in sample A.

SAMPLES 2065335-A, -B and -C:
Similar alteration assemblages of epidote + actinolite + plagioclase + minor titanite ± calcite ± trace magnetite are observed in all of these samples. The alteration assemblage suggests P-T conditions of the greenschist facies prevailed at the time of alteration, a moderate amount of fluid infiltrated the rocks, and the abundance of epidote and paucity of calcite indicates very low CO_2 in the fluid. Absence of foliation suggests that the alteration occurred in a static environment (ie no directed stress regime).

In samples 2065335-A and -B, fine-grained alteration textures of precursor meta-?sediments have been replaced by a fine-grained massive assemblage of epidote + actinolite + plagioclase + trace titanite. The laminated microstructure of 2065335-A allows a laminated sedimentary or meta-sedimentary precursor rock.

In samples 2065335-A and -C, partly-preserved textures allow identification of a granitoid protolith, possibly of ?monzonitic composition (primary alkali feldspar + plagioclase + ferromagnesians + minor ilmenite + trace zircon). Large primary alkali feldspar crystals lend a subporphyritic texture to the rock, presence of minor ilmenite suggests that the magma was reduced, and presence of small zircons within ferromagnesian grains and within or at margins of ilmenite confirms the magma was saturated early in zircon components. Alteration minerals identical to those in the altered meta-sediment confirms that the granitoid and meta-sediments were modified by the same aqueous fluid.

SAMPLES 2065337, -338:
Both of these samples are considered to represent hydrothermal breccia which formed in the epithermal environment, possibly as part of a surficial siliceous sintery deposit. Clasts are composed of quartz + minor hematite + monazite which formed in an early stage of epithermal deposits, and were subsequently enclosed by a late epithermal cement of quartz + minor clay. Any mineralisation is likely to be confined to the early-formed assemblage, not the late-formed cement. Both samples have been slightly modified by weak oxidation effects, where new very fine hematite clouding formed in the hematite-bearing clasts.

SAMPLES 2065340, -341, -342:
All of these samples are quartz-hematite-monazite epithermal rocks. All are composed of early-formed patches of millimetre to centimetre size composed of quartz + hematite + minor monazite, enclosed in matrix of similar mineralogy. The early patches contain finer-grained quartz, and the later matrix contains coarser-grained quartz, but the quartz in both parageneses displays similar textures especially subradiating internal microtexture and abundant tiny fluid inclusions. The similarities suggest that these deposits crystallised in two stages from a single silica-Fe-P-REE-bearing hydrothermal fluid.

SAMPLES 2065343-A and -B:
Both samples represent quartz-hematite-monazite epithermal rocks. They display paragenetic assemblages of minor early subhedral quartz crystals, overgrown by abundant subradiating quartz grains and associated hematite (with trace pyrite inclusions) and monazite, with late subradiating quartz projecting into minor vughs. The subradiating quartz contains abundant tiny fluid inclusions loosely concentrated in crystal growth faces. All of these minerals are considered to have crystallised in their paragenetic stages from a single silica-Fe-P-REE-bearing hydrothermal fluid. Minor vughs in sample 2065343A are filled by fine-grained sericite + hematite which crystallised from a small amount of later fluid of different composition.

SAMPLES 2065345, -346:
Both samples represent a quartz-hematite-monazite epithermal deposit, inferred to have crystallised from silica-Fe-P-REE-bearing hydrothermal fluid as open space-filling deposit. Both display a similar paragenetic sequence: early finer-grained quartz + hematite + monazite is overgrown by later-formed quartz. The quartz in both assemblages displays subradiating internal microstructure and minute fluid inclusions. The paragenetic assemblages produce a patchy appearance in the hand sample, where darker patches contain hematite intergrown with quartz, and whitish matrix is composed entirely of quartz.

SAMPLES 2065348, -349:
Both samples represent matrix-supported, non-sorted diamictite-type sediment, composed of minor larger clasts up to ~1 cm in size, in finer-grained (sand to silt) matrix. The larger clasts included sericite-hematite altered felsic crustal rocks (possibly granitoid) and minor meta-sedimentary clasts, in matrix composed of abundant crystal fragments (quartz >> K-feldspar >> hematite, muscovite, tourmaline, rutile, zircon) and clays. Recrystallisation of the matrix at relatively low P-T conditions produced fine-grained sericite + hematite. Different generations of hematite are inferred: hematite was present as sericite-hematite alteration in the source of the sedimentary components, as fine-grained hematite in the matrix during deposition, and as fine-grained hematite during low-grade recrystallisation of the matrix.

SAMPLES 2065350, -351, -352:
These rocks represent a range of clastic sediments, including siltstone, sandstone and granule breccia. The finer-grained sediments are composed of crystal fragments (K-feldspar, quartz, muscovite, hematite, rutile) in fine-grained recrystallised sericite matrix. The same silty matrix is observed in the coarser sediments which contain large angular lithic fragments of varied types (mostly of sericite-hematite altered felsic crystalline type, with fine-grained and medium-grained sediments, and micrographic granitoid). The crystal fragments of the finer-grained siltstones and sandstone, and the matrix of the coarser sediments, appear to have been derived mainly from the sericite-hematite altered felsic crystalline rock source. Textures suggest that the felsic crystalline rocks suffered sericite-hematite alteration prior to deposition, and minor new hematite formed pervasively during weak recrystallisation of the clay matrix at relatively low P-T conditions.

SAMPLES 2065354-A and -B:
Both samples formed as unsorted, non-layered pebbly sandstone (diamictite). It was composed of minor larger lithic clasts (sericite-monazite altered felsic granitoid; sericite-altered felsic metamorphic rock possibly ?gneiss) in a matrix composed of medium sandy crystal fragments (quartz >> K-feldspar) and fine-grained clays. Recrystallisation of the clay matrix at moderately low P-T conditions produced new fine-grained non-foliated sericite. Later weak oxidation produced a weak yellow-brown stain of goethite pervasively through the sericitic matrix.

SAMPLES 2065358-A and -B:
Both samples formed as a non-sorted, non-layered granule sandstone (diamictite), composed of minor larger lithic fragments (metamorphic felsic crystalline rock, meta-silty sedimentary rocks, non-metamorphosed micrographic granitoid) in a sandy matrix (quartz, K-feldspar, muscovite, hematite/magnetite, clays). Low-grade recrystallisation of the matrix clays produced fine-grained sericite which firmly binds the rock. Later near-surface oxidation produced fine-grained hematite in irregularly distributed patches.

SAMPLES 2065360-A and -B:
Both samples were deposited as non-sorted, non-layered pebbly sandstone (diamictite). Larger lithic fragments were composed of biotite-bearing meta-sedimentary rocks (ie at least middle greenschist facies), and non-metamorphosed but sericite-altered micrographic granitoid. Finer-grained matrix was composed mostly of sandy crystal fragments, but finer-grained matrix included clays and tiny silty clastic particles. Recrystallisation of the matrix clays at relatively low P-T conditions produced fine-grained non-foliated sericite. Later near-surface oxidation produced fine-grained pervasive hematite staining in the matrix, leaving ovoid pale yellow-brown kernels where the oxidised fluid failed to infiltrate the rock.

SAMPLES 2065362-A, -362-B, -364, -365:

These rocks crystallised from silica-Fe(-?S)-bearing hydrothermal fluids to produce massive and colloform banded deposits of quartz ± hematite ± sulfide (?pyrite). Dominant quartz in these rocks formed with varied textures which define paragenetic (timing of mineral formation) sequences: earliest quartz ± hematite ± sulfide, later coarser subradiating quartz with local vughs, later fine-grained gel-like quartz + trace hematite zoning in quartz grains, and latest coarse massive granular quartz. Banding and paragenetic variation is most evident in 2065362-A and -B. Overprinting oxidation has partly to completely obscured the hematite and sulfide minerals.