PETROGRAPHIC REPORT ON THIRTY-TWO OUTCROP ROCK AND DRILL CORE SAMPLES FROM LAKE CETHANA, NORTH-CENTRAL TASMANIA

For

Pluton Resources Limited

Reference: Email from John McDougall 31-3-10. Sample receipt 9-4-10.

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ABN 59 334 039 958

June, 2009

Report #635

SUMMARY

A suite of twenty-nine surface rock samples, labelled 152837-9, 152840a and b, 152841-3 and 152845-65, together with three drill core samples from drill hole CETD1 at intervals between 363.5 m and 467.7 m downhole, were submitted for petrographic preparation, examination and interpretation. The samples are from the Cambrian age Bull Creek Volcanics in the Lake Cethana area of north-central Tasmania. In addition, a thin section of a drill core sample (CETD1 589.9 m) previously described (Report #544, February 2009) was requested to be re-examined, with reference to the occurrence of secondary biotite.

For the 32 newly submitted samples, polished thin sections (PTS) were prepared from two of the drill core samples (CETD1 363.5 m and 467.7 m), with standard thin sections (TS) being prepared from all other samples. The petrographic preparation was performed by Petrographic International Pty Ltd in Brisbane. PTS were examined microscopically in transmitted and reflected light and TS in transmitted and oblique reflected light. Two section offcuts (152840b and 152859) were treated with hydrofluoric acid and sodium cobaltinitrite to check for the presence of K-feldspar. All samples were measured for magnetic susceptibility.

Summary descriptions of the 32 samples submitted in this batch are listed following:

152837 TS
Summary: Metamorphosed medium to coarse grained epiclastic sandstone, derived from a dacitic to andesitic source. There are abundant rather tightly packed detrital grains of plagioclase, with lesser amounts of quartz, lithics, ferromagnesian and FeTi oxide grains, all of which have an igneous derivation, with plagioclase, quartz and ferromagnesian grains probably representing disaggregated phenocrysts. There is only a minor matrix component and it has been completely recrystallised. The rock was largely replaced by a metamorphic assemblage (except for relict quartz, FeTi oxide and trace apatite grains) of albite and actinolite, with minor biotite, finely granular magnetite and a little titanite. This assemblage indicates that metamorphism has attained at least biotite grade.

152838 TS
Summary: Metamorphosed medium to coarse grained lithic-crystal epiclastic sandstone, derived from a largely dacitic source. The rock contains abundant fine grained recrystallised lithic grains (probably felsic volcanic material including porphyritic types, as well as fine grained quartzofeldspathic siltstone), along with a lesser proportion of relict quartz and altered plagioclase grains, a few altered ferromagnesian grains and a little relict FeTi oxide (e.g. titanomagnetite) and apatite. A minor matrix component was interstitial to the detrital grains. The rock was metamorphosed, at least to biotite grade, with replacement of lithic material, plagioclase, ferromagnesian grains and the matrix by an assemblage of actinolite, quartz, albite and biotite, with minor magnetite, carbonate and titanite and a trace of epidote.

152839 TS
Summary: Metamorphosed medium to coarse grained lithic-crystal epiclastic sandstone, or pyroclastic rock, derived from a felsic volcanic (e.g. dacitic) source. Relict textures are only moderately preserved due to imposed penetrative deformation and later metamorphic

recrystallisation effects. The original rock contained abundant fine grained volcanic lithic, quartz and plagioclase grains and a finer grained matrix, with minor FeTi oxide and apatite grains. The rock was initially deformed, developing a weak foliation. There was subsequent metamorphic recrystallisation that developed a randomly oriented metamorphic assemblage that is dominated by quartz, albite and biotite, with subordinate actinolite. Minor magnetite and a little pyrite tend to be concentrated in biotite aggregates. Metamorphism has evidently achieved at least biotite grade.

152840a TS

Summary: Metamorphosed coarse lithic-crystal felsic tuff or epiclastic, with an early weak foliation overprinted by fine grained metamorphic recrystallisation. The rock was dominated by lithic fragments of fine grained, commonly porphyritic felsic volcanic rock which had a very fine grained (?aphanitic) groundmass and possible fluidal and/or vitriclastic texture, with a few quartz, plagioclase and ferromagnesian (probably biotite) phenocrysts. In-between the larger lithic fragments, there are smaller lithic grains and isolated disaggregated phenocrystal grains of quartz, plagioclase and minor ferromagnesian material. Weak foliation is defined by preferred orientation of the lithic fragments. The rock has been subsequently affected by metamorphism, with fine grained recrystallisation of lithic fragment groundmass material to quartz, albite, K-feldspar and biotite. There is also formation of fine grained biotite aggregates in the interstitial sites and at former ferromagnesian sites. A little actinolite, epidote and chlorite have formed as metamorphic minerals. The metamorphic assemblage is indicative of metamorphism to biotite grade.

152840b TS

Summary: Coarse grained felsic volcanic fragmental rock, e.g. lithic-crystal tuff, with evidence of imposed hydrothermal alteration and metamorphic effects. The original rock was dominated by coarse fragments of fine grained, locally fluidal texture, porphyritic felsic volcanic rock (e.g. of dacitic composition). The fragments contained phenocrysts of quartz, plagioclase and ferromagnesian material in a possibly aphanitic quartzofeldspathic groundmass. The rock also contains a few disaggregated phenocrystal grains of quartz, plagioclase and ferromagnesian material. Metamorphic effects are expressed by finely granular recrystallisation of groundmass material to albite, K-feldspar and quartz, with minor actinolite. There was replacement of plagioclase phenocrysts by K-feldspar, albite and minor quartz, carbonate, epidote and actinolite, with former ferromagnesian material being replaced mostly by actinolite, with minor biotite and a little carbonate and magnetite. Subsequently, most biotite was replaced by chlorite. The rock also contains traces of disseminated pyrite and chalcopyrite.

152841 TS

Summary: Metamorphosed, foliated fine grained porphyritic felsic volcanic rock, possibly ignimbritic in character. It is dominated by fine grained, altered felsic volcanic material, with a few elongate fiamme, now replaced largely by fine grained sericite. The dominant, originally aphanitic or glassy material contained scattered quartz phenocrysts along with a few microphenocrysts of FeTi oxide (titanomagnetite). Initially, the rock was subjected to weak deformation, causing development of a weak foliation. There was probably low grade regional metamorphism and/or hydrothermal alteration, causing replacement by fine grained quartz and abundant sericite, with minor albite. The rock was subsequently subjected to thermal metamorphism, resulting in development of disseminations and aggregates of fine grained biotite, with a little chlorite and magnetite.

152842 TS

Summary: Lithic-crystal-vitric felsic tuff, or reworked epiclastic rock, with weakly developed foliation. It is dominated by former medium to coarse lithic grains of fine grained siltstone and felsic volcanic material, in a fine vitriclastic matrix. There are also scattered disaggregated former phenocrystal quartz grains. The rock experienced early strong alteration to patchy chlorite and sericite, along with finely granular quartz and albite. A few

irregular patches and anastomosing veins were emplaced at the early stage and could have contained quartz, chlorite, sericite and magnetite. The rock was subsequently affected by a thermal metamorphic overprint that caused the patchy development of fine grained metamorphic biotite. Several sub-parallel quartz-rich veins were emplaced, containing fine to medium grained "epithermal-like" infill textures. Later, most magnetite was replaced by hematite and the rock slightly affected by supergene oxidation with development of patchy goethite staining.

152843_TS

Summary: Lithic-crystal felsic tuff, or reworked epiclastic rock that has undergone initial strong hydrothermal alteration, with imposed weak foliation and a subsequent thermal metamorphic overprint. The rock contains abundant altered felsic volcanic lithic fragments, perhaps of vitriclastic and pumiceous material, with some being sparsely porphyritic. The fragments include "fiamme-like" elongate aggregates. There is also a subordinate population of relict phenocrystal quartz grains, along with a few altered ferromagnesian and feldspar grains and a little FeTi oxide. It is likely that hydrothermal alteration caused strong replacement by an assemblage of quartz, sericite and chlorite, with the layer silicates being concentrated into the fiamme-like aggregates and their preferred orientation defining a weak foliation. Later metamorphism caused the formation of minor randomly oriented biotite, mostly in the fiamme-like aggregates and at former ferromagnesian grain sites. Slight weathering effects have caused goethite staining and fracture-controlled veinlike masses.

152845_TS

Summary: Felsic vitric-crystal tuff, possibly ignimbritic, originally containing abundant fine vitriclastic material as well as larger pumiceous fragments, scattered relict quartz phenocrysts and a few altered phenocrystal grains of ferromagnesian phases, feldspar and FeTi oxide. The rock probably experienced initial hydrothermal alteration, with replacement by a fine grained assemblage of quartz, sericite and chlorite. Subsequently, a thermal metamorphic event might have destroyed chlorite and formed widespread fine grained biotite, concentrated at former ferromagnesian and some of the vitriclastic fragment sites.

152846_TS

Summary: Metamorphosed, hydrothermally altered porphyritic felsic volcanic rock, perhaps originally of dacitic composition. The rock retains relict quartz phenocrysts and would have contained scattered phenocrysts of ferromagnesian material (probably biotite mostly) and a few of feldspar. The groundmass was fine grained (perhaps aphanitic), with relict fluidal texture and was of quartzofeldspathic composition. There is no diagnostic relict textural evidence that the rock was originally epiclastic or pyroclastic in character. It is interpreted that there was initial strong hydrothermal alteration, with replacement of the rock by quartz, sericite and subordinate chlorite. Weak deformation was imposed, leading to a weak foliation being expressed in sericite-rich zones. Subsequent thermal metamorphism led to crystallisation of fine grained biotite and a little magnetite throughout, but concentrated at former ferromagnesian sites. The rock is also cut by a few veins of quartz, with a little biotite, epidote and magnetite.

152847_TS

Summary: Porphyritic felsic volcanic rock, with relict quartz phenocrysts and altered former phenocrystal grains of feldspar, ferromagnesian material (probably biotite) and a little FeTi oxide, in a formerly fine grained quartzofeldspathic groundmass. Although relatively homogeneous, the groundmass does show possible fragmental (and fine vitriclastic) texture in places, implying that the rock might have originally been ignimbritic. Strong hydrothermal alteration is implied, with replacement of the original rock by fine grained quartz, sericite and chlorite, with trace leucoxene. Original FeTi oxide grains were mostly replaced by hematite and leucoxene. A weak to moderate foliation prevails, defined by preferred orientation of layer silicates and altered feldspar grains and altered fragments. A possible metamorphic

overprint is reflected in the incipient formation of fine grained biotite and magnetite, with most magnetite being replaced by hematite. A couple of anastomosing quartz veins were emplaced, mostly parallel to foliation. Weathering effects are manifest by patchy goethite development, especially along foliation planes.

152848_TS

Summary: Hydrothermally altered, deformed and metamorphosed porphyritic felsic volcanic rock, possibly a type of ignimbrite originally. It contained scattered phenocrysts of quartz, along with possible elongate lithic/vitric fragments and phenocrystal grains of ferromagnesian phases, feldspars and trace FeTi oxide. The groundmass appears to have been composed of fine vitriclastic material and displays a possible weak primary foliation. Hydrothermal alteration caused replacement of much of the rock by fine grained quartz and subordinate sericite and chlorite, along with development of a few replacive quartz aggregates in the groundmass. Later thermal metamorphism led to further recrystallisation, and concentrations of fine grained biotite, sericite, chlorite and a little magnetite and tourmaline at former lithic/vitric fragment, ferromagnesian and feldspar phenocryst sites. There was later replacement of igneous FeTi oxide and metamorphic magnetite by hematite. Weathering effects caused considerable goethite impregnation.

152849_TS

Summary: Felsic vitric-crystal tuff, possibly ignimbritic, with strong hydrothermal alteration effects, deformation and a later imposed thermal metamorphic overprint. The rock originally contained a few large quartz phenocrysts, along with possible phenocrysts of feldspar, ferromagnesian material and a few grains of FeTi oxide, as well as possible lithic/vitric fragments. The groundmass was fine grained, of quartzofeldspathic composition and contained vitriclastic material, with vague flow foliation. Alteration caused replacement of the rock by fine grained sericite, quartz and chlorite, and a subsequent moderate foliation was imposed by deformation. Later, the thermal metamorphic effect led to growth of fine grained biotite, largely at former ferromagnesian and lithic grain sites. Weathering effects were responsible for patchy goethite impregnation.

152850_TS

Summary: Strongly hydrothermally altered, deformed and subsequently thermally metamorphosed vitric-crystal felsic tuff, probably of ignimbritic character. The rock retains scattered large relict quartz phenocrysts and clusters of phenocrysts, and has a few pseudomorphs after former possible ferromagnesian and feldspar phenocrysts. The original groundmass was quartzofeldspathic, with local pumiceous aggregates and fine vitriclastic material. Alteration caused replacement of the rock (except quartz phenocrysts) by fine grained sericite and minor quartz and chlorite. A moderate foliation was also imposed, defined by preferred orientation of the layer silicates and there was also local fracturing and recrystallisation of the quartz phenocrysts. Thermal metamorphism led to development of minor fine grained, randomly oriented biotite. Slight weathering effects were later imposed, resulting in patchy goethite impregnations.

152851_TS

Summary: Weathered felsic vitric-crystal tuff (possibly ignimbritic). The rock retains scattered relict phenocrystal grains of quartz, but other phenocrystal grains of feldspar and ferromagnesian material, plus lithic/vitric are completely altered. The original groundmass was fine grained and possibly dominated by vitriclastic material. Hydrothermal alteration caused replacement of the rock by fine grained quartz and sericite, with minor chlorite. A weak anastomosing foliation was imposed and it is likely that there was a subsequent thermal metamorphic overprint, developing a little fine grained biotite, mainly at pseudomorphic aggregates sites. Weathering led to significant degradation of chlorite and biotite to nontronite and the formation of goethite impregnations.

152852_TS

Summary: Vitric-crystal felsic tuff, with hydrothermal altered and later thermal metamorphic effects, overprinted by pervasive weak weathering. The rock retains scattered relict phenocrystal grains of quartz, with pseudomorphs after possible vitric/lithic fragments and feldspar and ferromagnesian phenocrysts. The groundmass is fine grained, recrystallised by has vague preservation of fine vitriclastic and pumiceous texture. There is no indication that the rock represents an epiclastic sandstone. Hydrothermal alteration caused replacement by finely granular quartz, subordinate sericite, minor chlorite and trace leucoxene. Later metamorphism led to development of minor fine grained biotite, with subsequently imposed weathering causing partial degradation of chlorite and biotite to nontronite and goethite.

152853_TS

Summary: Metamorphosed, altered felsic vitric-crystal-lithic tuff. The rock retains a few relict phenocrystal grains of quartz and diffuse pseudomorphs after former feldspar and ferrmagnesian phenocrysts. There are also a couple of possible porphyritic lithic fragments. All occur in a fine grained vitriclastic to pumiceous groundmass. Initial hydrothermal alteration probably caused replacement by an assemblage of quartz, sericite and chlorite. Subsequently, thermal metamorphism produced considerable fine grained biotite, concentrated at former ferromagnesian sites and to a lesser extent in the groundmass. Feldspar phenocrysts were mostly replaced by granular, fine grained quartz. The groundmass is dominated by granular quartz, with subordinate sericite and biotite. Most igneous FeTi oxide and the small amounts of fine grained granular metamorphic magnetite were later replaced by hematite.

152854_TS

Summary: Felsic vitric-crystal tuff with strong phyllic (quartz-sericite) alteration and subsequent deformation effects. The original rock contained scattered quartz phenocrysts and could have contained a minor amount of feldspar and ferromagnesian phenocrysts, in a fine grained vitriclastic groundmass. Apart from quartz phenocrysts, the remainder of the rock was completely altered and replaced by fine grained quartz, with a network of weakly to moderately foliated sericite-rich foliae intervening. Traces of leucoxene and pyrite were formed as part of the alteration, with pyrite being later replaced by goethite due to supergene oxidation.

152855_TS

Summary: Felsic vitric-crystal-lithic tuff showing scattered relict phenocrystal grains of quartz in a fine groundmass that was dominated by fine pumiceous material and which contained probable ferromagnesian phenocrysts and lithic/vitric fragments, along with a few relict grains of apatite and zircon and small altered grains of FeTi oxide. The rock underwent strong phyllic alteration, with replacement by quartz and sericite, with subsequent development of locally weak to moderate foliation. A thermal metamorphic effect could have been imposed with development of minor fine grained biotite and magnetite. Later, oxidative retrograde alteration caused most magnetite and igneous FeTi oxide to be replaced by hematite.

152856_TS

Summary: Porphyritic dacite, with evidence of a metamorphic and/or hydrothermal overprint. The rock retains a few quartz phenocrysts and also contained scattered plagioclase and ferromagnesian phenocrysts, along with a little FeTi oxide and apatite in a fine to medium grained, largely feldspathic groundmass. There was significant replacement of the primary igneous minerals, with plagioclase being mostly altered to albite and K-feldspar and ferromagnesians to actinolite, epidote and fine grained (secondary) biotite, plus a little magnetite. The alteration mineral assemblage is consistent with either having formed by biotite grade thermal metamorphism, or by pervasive hydrothermal alteration of transitional potassic-propylitic type.

152857_TS

Summary: Altered porphyritic dacite, containing a few relict quartz phenocrysts and pseudomorphs after former ferromagnesian and plagioclase phenocrysts in a fine grained, dominantly feldspathic groundmass. Relict shapes of the ferromagnesian pseudomorphs suggest that biotite as well as hornblende or pyroxene were originally present. The rock underwent strong alteration, with replacement of all original feldspar by albite, K-feldspar and a little quartz, epidote and actinolite. Ferromagnesian phases were almost completely replaced by actinolite, with minor epidote and chlorite, and traces of titanite, magnetite and pyrite. Traces of pyrite and chalcopyrite occur in the altered groundmass. The alteration is consistent with either having formed by low grade thermal metamorphism, or by pervasive hydrothermal alteration of transitional potassic-propylitic type.

152858_TS

Summary: Altered porphyritic dacite, containing a few relict quartz phenocrysts and pseudomorphs after former ferromagnesian and plagioclase phenocrysts in a fine grained, dominantly feldspathic groundmass. The rock was replaced by a generally fine grained assemblage of albite, K-feldspar, quartz, actinolite and epidote, with a few irregular to veinlike aggregates of clinopyroxene, actinolite and minor epidote, magnetite and K-feldspar. There is also a trace of disseminated pyrite and rare chalcopyrite. The alteration is consistent with either having formed by thermal metamorphism (possibly to hornblende hornfels facies), or by pervasive hydrothermal alteration of "mafic potassic" type.

152859_TS

Summary: Altered fractured porphyritic dacite, possibly representing a coarse volcaniclastic rock. There are a few relict quartz phenocrysts and rather abundant albitised plagioclase phenocrysts, along with pseudomorphic aggregates that represent sites of former ferromagnesian phenocrysts. The groundmass of the rock was fine grained and feldspathic and there are also a few relict grains of FeTi oxide (titanomagnetite) and apatite. The rock was replaced by abundant albite, K-feldspar and quartz in the fractured, altered groundmass, and with abundant fine grained biotite, developed at former ferromagnesian sits and in fractures in the groundmass. A little chlorite, actinolite and titanite are associated with biotite. The alteration mineral assemblage could reflect metamorphism of the original rock to biotite grade, or alternatively, it represents the influence of pervasive potassic-propylitic alteration.

152860_TS

Summary: Strongly altered porphyritic dacite, possibly of pyroclastic origin, and strongly recrystallised. The original rock contained a few phenocrysts of quartz and there are pseudomorphs after former ferromagnesian phenocrysts and a few small feldspar phenocrysts. The groundmass was of quartzofeldspathic composition, but recrystallisation has obscured definitive relict features; however, it is speculated that it could have included pumiceous material, including elongate fragments. Alteration has led to replacement of the groundmass and feldspar phenocrysts by fine, inequigranular K-feldspar, albite and quartz, with ferromagnesian components replaced mostly by actinolite, epidote and minor biotite. Weakly foliated biotite is characteristically developed in the recrystallised groundmass. The alteration assemblage could be due to biotite grade metamorphism or alternatively to pervasive "mafic potassic" hydrothermal alteration.

152861_TS

Summary: Porphyritic dacite, with strong alteration, perhaps caused by biotite grade metamorphism, or pervasive hydrothermal alteration of "mafic potassic" or transitional propylitic-potassic type. The rock retains a few relict quartz phenocrysts and a few microphenocrysts of FeTi oxide and apatite. Former plagioclase and ferromagnesian phenocrysts are completely altered. The groundmass appears to have been coherent, fine to medium grained, inequigranular and of broadly feldspathic composition. Alteration has led to replacement of much of the rock by albite, K-feldspar and subordinate quartz, biotite, actinolite and minor epidote, with a few replacive patches dominated by actinolite and biotite.

152862 TS

Summary: Porphyritic dacite, possibly with pumiceous quartzofeldspathic groundmass, and with strong alteration caused by biotite grade metamorphism, or by pervasive hydrothermal alteration of "mafic potassic" type. The rock contains scattered relict quartz phenocrysts, pseudomorphs after former ferromagnesian phenocrysts, as well as after a few plagioclase phenocrysts. The groundmass appears to have relict pumiceous texture, with a few possible fragments and weak flow foliation. Subsequently, the rock underwent penetrative deformation, with development of a tectonic foliation. Alteration led to replacement of the groundmass and feldspar phenocrysts by finely inequigranular albite, quartz, K-feldspar and biotite. The rock also has scattered replacement aggregates of dominant biotite, K-feldspar and actinolite, with a little epidote, titanite, magnetite, pyrite and pyrrhotite, at former ferromagnesian sites and in the groundmass.

152863 TS

Summary: Strongly porphyritic hornblende-quartz andesite (or microdiorite), possibly representing a shallow intrusive. The rock displays strong pervasive alteration. It has abundant altered plagioclase phenocrysts, less common, variably altered ferromagnesian phenocrysts (including relict brown hornblende) and a few quartz phenocrysts. The groundmass component was dominated by plagioclase and had a fine grained, inequigranular texture, with a few entrained microphenocrysts of FeTi oxide (titanomagnetite) and apatite. Alteration of the rock led to albitisation of plagioclase and extensive replacement of ferromagnesian material, and in places the groundmass, plagioclase and quartz phenocrysts, by actinolite and biotite, with minor epidote and magnetite. This assemblage could be due to biotite grade thermal metamorphis, or alternatively represent the product of pervasive "mafic potassic" hydrothermal alteration.

152864 TS

Summary: Coarsely quartz-porphyritic felsic volcanic rock, perhaps of rhyodacite composition, with imposed alteration, deformation and metamorphic effects. Apart from quartz phenocrysts, the rock had a few ferromagnesian phenocrysts and one or two feldspar phenocrysts, along with a few apatite microphenocrysts. The groundmass was fine grained, or quartzofeldspathic composition and with possible flow foliation. Early alteration could have caused the groundmass to be replaced by an assemblage of K-feldspar, quartz, albite and sericite, and there was development of a weak foliation and local "pressure shadows" about relict quartz phenocrysts. Metasomatic replacement patches developed prior to, or during biotite grade metamorphism and are now manifest as fine to medium grained aggregates of K-feldspar, with minor epidote, chlorite and quartz. Former ferromagnesian grains are pseudomorphed by fine grained biotite.

152865 TS

Summary: Hydrothermally altered, deformed and subsequently metamorphosed porphyritic felsic volcanic rock, possibly originally of rhyodacitic composition. The rock retains scattered quartz phenocrysts, but all other phenocryst phases (ferromagnesians including biotite, and possible feldspar) were completely altered. The phenocrysts occurred in a fine grained quartzofeldspathic groundmass. It is interpreted that initial alteration might have produced a fine grained assemblage of quartz and sericite, with lesser amounts of K-feldspar and chlorite. Imposed deformation led to development of a moderate foliation, defined mostly by sericite aggregates. Subsequent metamorphism led to destruction of chlorite and crystallisation of significant fine grained biotite, overprinting the foliation and associated with traces of magnetite (partly altered to hematite) and tourmaline.

CETD1 363.5 m PTS

Summary: Hydrothermally altered, deformed and metamorphosed laminated volcaniclastic sandstone and siltstone. Compositional laminations are diffusely preserved and the sandstone component has a matrix-supported texture, with scattered detrital grains of former

volcanic phenocrystal quartz and a few grains of altered FeTi oxide and relict apatite in a recrystallised silty matrix. The siltstone component has scattered small, partly recrystallised detrital quartz grains. Matrix material in the rock was apparently hydrothermally altered, with formation of an assemblage of fine grained quartz, chlorite and sericite, with a small amount of sulphides and leucoxene. A moderate foliation was imposed, defined by preferred orientation of the layer silicates and oblique to the bedding laminations. Subsequently, the rock may have been thermally metamorphosed, with development of a little randomly oriented biotite, porphyroblastic pyrite, a little fine grained magnetite and trace chalcopyrite.

CETD1 442.6 m TS

Summary: Porphyritic, fine grained felsic igneous rock, possibly representing a volcanic or shallow intrusive and containing scattered quartz phenocrysts in a fine grained quartzofeldspathic groundmass. The rock is strongly to intensely altered. The nature of early alteration is obscure, but part of the rock shows indications of thermal metamorphism, causing replacement of the groundmass by finely granular quartz, K-feldspar and biotite, with patchy sericite and a little epidote and chlorite. This zone borders on to the intense alteration zone where the rock is almost completely replaced by fine to medium grained epidote and chlorite, with subordinate interstitial quartz, minor pumpellyite and a little carbonate, magnetite, titanite and pyrite. The intense alteration appears to be retrograde with respect to the biotite-bearing metamorphic assemblage and implies considerable metasomatic introduction of Ca, Mg and Fe.

CETD1 467.7 m PTS

Summary: Compositionally laminated felsic volcaniclastic rock, ranging from matrix-supported coarse lithic-crystal sandstone to finer grained siltstone. Former phenocrystal quartz grains are common and there are scattered lithic fragments, some of which retain porphyritic texture. The rock was probably initially hydrothermally altered, with replacement by fine grained quartz, sericite and chlorite, with a little disseminated sulphides. Deformation was imposed, causing a moderate foliation, defined by preferred orientation of the layer silicates. The rock was later subjected to thermal metamorphism and probable hydrothermal introduction of components, with overprinting and replacement of the deformed assemblage by fine grained randomly oriented biotite, with accompanying magnetite, pyrite and a little chalcopyrite. It is possible that pyrrhotite was originally present, but was replaced by pyrite and marcasite.

Interpretation and comment

All of the samples examined represent porphyritic, fine grained felsic igneous rocks (mostly volcanics and including pyroclastic and possibly coherent lava and/or shallow intrusive types), with a few compositionally and texturally related epiclastic rocks (e.g. volcaniclastic sandstone and siltstone). These primary rock types have experienced varying amounts of early hydrothermal alteration, with subsequently imposed penetrative deformation (and likely low grade regional metamorphism), followed by a later thermal metamorphic (and locally metasomatic) overprint.

Variations in primary textures, phenocryst mineralogy and proportions indicate that there are possibly four major compositional groups in the suite, albeit with probably limited difference between groups. Two major groups are:

1) felsic lithic-crystal tuff, including ignimbritic variants and those with fine grained vitriclastic groundmass (e.g. 152840a, b, 152841-3, 152845, 152847-55)
2) porphyritic dacite, perhaps mostly coherent material (e.g. lava and/or shallow intrusive), but including possible pyroclastic variants (e.g. 152846, 152856-62) and with 152863 being slightly more mafic (e.g. hornblende-quartz andesite or microdiorite)

Smaller populations of samples are identified as;

3) porphyritic rhyodacite (e.g. 152864-5, CETD1 442.6 m) and
4) epiclastic sandstone, in places intercalated with siltstone and derived from a proximal porphyritic (quartz-phyric) felsic volcanic source (e.g. 152837-9, CETD1 363.5 m, CETD1 467.7 m).

The felsic lithic-vitric tuffs contain prominent relict quartz phenocrysts and have pseudomorphs after generally less common feldspar (probably plagioclase mostly) and ferromagnesian phenocrysts, along with altered lithic/vitric grains (and larger fragments). Where discernable, the groundmass may have been dominated by fine vitriclastic material (e.g. fine glass shard), with coarser pumiceous material locally. Lithic/vitric fragments are commonly porphyritic and some elongate types strongly resemble the fiamme found in ignimbrites. Most samples contain traces of relict apatite and zircon, as well as variably altered microphenocrysts of FeTi oxide (titanomagnetite). It is evident that groundmass material was of quartzofeldspathic composition and the overall rock composition may have ranged from rhyodacite to dacite. It is likely that the less common, coherent rhyodacite (group 3 above) was similar in composition to the tuffs, having the same phenocryst types and representing lava or shallow intrusive material. The porphyritic dacites are slightly more mafic in composition. They retain quartz phenocrysts (but commonly sparser than in the felsic lithic-vitric tuffs and rhyodacite) and ferromagnesian phases can be locally more abundant. Relict shapes after altered ferromagnesian phases suggest that hornblende and/or pyroxene were present, along with biotite. In 152863, relict brown hornblende phenocrysts are locally preserved. The porphyritic dacites also contain accessory grains of FeTi oxide, apatite and zircon, with the groundmass commonly being coherent and locally fluidal in texture, but in places being evidently holocrystalline and inequigranular in texture. The groundmass in the porphyritic dacites is feldspathic in composition. Sample 152863 is probably the least silicic, having only minor quartz phenocrysts and a higher proportion of ferromagnesian material and plagioclase; this rock is interpreted as a hornblende-quartz andesite or microdiorite, maybe representing a shallow intrusive. Interpreted epiclastic rocks (group 4 above) have relict clastic textures, with lithic grains in many, along with disaggregated (detrital) former phenocrystal phases, especially quartz. The epiclastic rocks represent redeposited volcanic material close to the source.

Relict compositional layering (bedding) is preserved in the samples from CETD1 and there is intercalation of thin laminae of volcaniclastic sandstone and siltstone. Detrital grains in the epiclastic rocks are hosted in a finer grained, originally silty matrix.

All samples in the suite show considerable modification of the primary mineralogy and textures due to imposed alteration and deformation phenomena. It can be implied that most samples were affected by moderate to strong pervasive hydrothermal alteration at an early, pre- to syn-tectonic stage. Two main types of early alteration are apparent. The stronger type was feldspar-destructive, resulting in assemblages of fine grained quartz, sericite and chlorite (varying amounts of each and mostly with sericite > chlorite), in places with a little associated leucoxene (fine rutile), pyrite and magnetite and/or hematite. This alteration ranges from propylitic to phyllic in character and is found in many of the felsic lithic-vitric tuffs and in the epiclastic rocks in CETD1. The other alteration type contains albite and/or K-feldspar, along with sericite, chlorite and leucoxene. In places, epidote, actinolite and pyrite could have been present. This type of alteration is probably of propylitic type, with the presence of K-feldspar being a reflection of primary rock composition (i.e. relatively potassic), rather than implying introduction of K (i.e. potassic alteration). In both of these alteration types, most primary igneous minerals were destroyed, with only quartz phenocrysts, apatite, zircon, and in places, FeTi oxide (titanomagnetite) being preserved.

The early alteration could have been due to broad scale hydrothermal circulation through a felsic volcanic-dominated pile (e.g. involving combinations of magmatic, marine and meteoric fluids) as well as due to low grade regional metamorphic processes (e.g. lower greenschist facies). The latter have definitely occurred and apparent in many samples in the suite by effects of penetrative deformation, expressed as a weak to moderate foliation and mainly defined by preferred orientation of sericite and chlorite. In places, there is also a strong preferred orientation of coarse lithic/vitric fragments, and the foliation can be observed in several rocks to wrap around relict quartz phenocrysts. About some relict quartz phenocrysts, there is local development of deformation-induced "pressure shadows". Foliation is strongest where there is an abundance of the layer silicate minerals. In the intercalated epiclastic sandstone/siltstone sample in CETD1 363.5 m, foliation is oblique to the compositional layering, but is parallel to layering in CETD1 467.7 m.

Post-dating the penetrative deformation, there is widespread indication in the majority of samples, for a subsequently imposed metamorphic and locally, metasomatic, overprint. There are two major new assemblages that have formed, with intergradation between the two. One shows development of minor through to common amounts of fine grained, randomly oriented biotite (ranging from greenish through khaki to brown in colour), and the other

shows development of actinolite, commonly with associated epidote. As mentioned, there is gradation in-between, such that actinolite + biotite ± epidote is a relatively common assemblage. The differences in the new assemblages are ascribed mainly to host rock compositional control, with the apparently more felsic (and potassic) lithic-crystal tuffs and rhyodacite containing biotite (± recrystallised quartz, sericite and local K-feldspar, albite, magnetite, epidote), and the slightly more mafic compositions (e.g. dacite) containing a higher proportion of actinolite, epidote, as well as biotite, K-feldspar, albite, quartz, magnetite and titanite. There is good textural evidence for the new assemblages to overprint earlier-formed foliation and to cause destruction of earlier alteration minerals (mainly chlorite). In most samples, the new mineral assemblages are consistent with development under metamorphic conditions of the albite-epidote hornfels facies (and at least at biotite grade). However, in one sample (152858), there is minor development of disseminated and veinlike clinopyroxene (e.g. in the diopside-hedenbergite series), with the implication that metamorphic conditions have attained hornblende hornfels facies. In fact, some of the green amphibole termed "actinolite" in the descriptions could be hornblende, but confirmation would need to be made by electron microprobe analysis. In a few samples, and most notably in CETD1 467.7 m, there is a conspicuous association of biotite with minor to significant magnetite, pyrite and traces of other sulphides (e.g. chalcopyrite, pyrrhotite, marcasite).

As indicated above, the new mineral assemblages that have overprinted the earlier deformed alteration assemblages could be ascribed to the effects of thermal metamorphism (e.g. caused by a nearby intrusive), but there are features that suggest, at least in some samples, there has been metasomatic introduction of components. This may have been largely pervasive as there are few indications of any significant veining. The pervasive metasomatic effects could be implied by greater development of biotite (and minor associated magnetite, epidote) and patchy flooding and local veining by finely granular K-feldspar (± quartz). It could also be implied by the local occurrence of irregular replacement aggregates of actinolite ± biotite ± epidote, and in CETD1 442.6 m by intense replacement by epidote + chlorite (+ quartz, pumpellyite, carbonate, titanite, magnetite, pyrite). Similarly, in a few samples, minor sulphides have developed in the new alteration assemblages. Traces of tourmaline form part of the new mineral assemblage in 152848 and 152865. Consequently, it can be implied (but not proven) that there could have been at least minor hydrothermal introduction of components including K, Fe, S (Cu, B) and in places Ca, Mg and Fe. The resulting alteration assemblages have affinities to transitional types between propylitic and potassic alteration and to "mafic potassic" alteration (the latter being partly controlled by host rock composition).

Veining is generally absent, or only a minor feature, in most rocks of the suite. The few veins that are observed are thin, do not have alteration selvedges and

mostly contain one or more of quartz, K-feldspar, biotite or muscovite. A little actinolite is observed in a vein in 152838 and clinopyroxene in 152858. Veins can be concordant with foliation, or cross-cutting.

Only minor indications of sulphide mineralisation are observed and where present is mostly disseminated and not in veins. A few samples have trace up to 2% of pyrite, but in CETD1 467.7 m, there is up to 5 % pyrite in disseminations and elongate aggregates, commonly associated with magnetite and minor associated chalcopyrite. This sample also has indications that pyrrhotite was originally present, but was later replaced by fine grained pyrite and marcasite. Trace pyrrhotite is present in 152862, along with a little pyrite and chalcopyrite. Sample CETD1 467.7 m also has the only significant amount of chalcopyrite (~1%). No other sulphides (or gold) have been recognised.

Supergene oxidation has affected a few samples, mostly of the felsic lithic-crystal tuff type. It is mostly indicated by patchy goethite staining, locally concentrated along fractures and foliation planes, and by degradation of layer silicates such as biotite and chlorite to nontronitic clay. Several samples have hematite replacing igneous FeTi oxide and alteration-derived magnetite; in part this could be a supergene effect, but it could also reflect low temperature retrograde alteration.

In conclusion, most samples in the suite of generally felsic volcanic and volcaniclastic rocks display effects of early hydrothermal and/or low grade regional metamorphic alteration and imposed penetrative deformation. Subsequently, there has been an overprint of at least biotite grade thermal metamorphism, with the latter process accompanied in places by possible effects of pervasive metasomatic replacement. These overprinting effects could be due to a nearby intrusive, with possible introduction of K, Fe and a little S, Cu and B, and locally significant Ca, Mg and Fe mobility. The later alteration has affinities to transitional propylitic-potassic and "mafic potassic" alteration types. Although these provide analogies with alterations proximal to some porphyry CuAu systems, the almost complete lack of fracturing and veining, and general paucity of sulphide mineralisation, suggest that if intrusion-related, the intrusive has not attained significant fluid saturation on crystallisation.

The same comments apply to the re-examination of the thin section from sample CETD1 589.9 m.

Individual sample descriptions

152837 TS

Summary: Metamorphosed medium to coarse grained epiclastic sandstone, derived from a dacitic to andesitic source. There are abundant rather tightly packed detrital grains of plagioclase, with lesser amounts of quartz, lithics, ferromagnesian and FeTi oxide grains, all of which have an igneous derivation, with plagioclase, quartz and ferromagnesian grains probably representing disaggregated phenocrysts. There is only a minor matrix component and it has been completely recrystallised. The rock was largely replaced by a metamorphic assemblage (except for relict quartz, FeTi oxide and trace apatite grains) of albite and actinolite, with minor biotite, finely granular magnetite and a little titanite. This assemblage indicates that metamorphism has attained at least biotite grade.

Handspecimen: The sample is composed of a dark grey volcaniclastic rock containing scattered feldspar and less common quartz, diffuse lithic and possible ferromagnesian grains, each up to a few millimetres across, in a finer grained recrystallised matrix. It is likely that the rock is metamorphic and developed fine grained biotite and amphibole in the matrix. It must also contain a little magnetite as it is strongly magnetic, with susceptibility up to 1370 x 10^{-5} SI units.

Petrographic description

a) Primary rock characteristics: In the section, relict texture is moderately well preserved. There is a rather tightly packed relict detrital grain texture, with abundant altered plagioclase grains up to 4 mm across, more sparsely scattered relict phenocrystal quartz grains up to 3.5 mm across, a few elongate recrystallised lithic grains up to 6 mm across as well as scattered grains of partly altered FeTi oxide (e.g. titanomagnetite) up to 0.5 mm across. There are a couple of pseudomorphs after possible former ferromagnesian grains up to 2.5 mm across and a trace of relict apatite. A minor finer grained matrix component occurred interstitially, and has been completely recrystallised. From the relict characteristics and bulk composition, it is interpreted that the rock represents a medium to coarse grained epiclastic sandstone, derived from a rather proximal andesitic to dacitic volcanic source.

b) Alteration and structure: It is evident that the volcaniclastic rock has been metamorphosed, with recrystallisation of the matrix and lithic grains, and replacement of original plagioclase and ferromagnesian grains. Plagioclase was replaced by albite, with minor invasion by green fine to medium grained actinolite. Ferromagnesian grains were replaced by actinolite and/or biotite, along with minor finely granular magnetite. A similar assemblage has formed from the recrystallisation of the matrix and lithic grains, with fine to medium grained actinolite predominating, but locally with abundant biotite, along with minor albite, granular magnetite and trace titanite and pyrite. Detrital grains of former igneous FeTi oxide are locally altered to titanite. Finely granular metamorphic magnetite is typically associated with biotite, but also occurs in actinolite aggregates. In places, a weak foliation is apparent, defined by slight preferred orientation of original detrital grains and of actinolite aggregates. The metamorphic mineral assemblage indicates that metamorphism has attained at least biotite grade.

c) Mineralisation: The sample contains minor relict grains of former igneous FeTi oxide (titanomagnetite) up to 0.5 mm across. Minor finely granular magnetite (up to 0.2 mm) has formed as part of the metamorphic assemblage in company with biotite and actinolite. A trace of pyrite, in grains up to 0.3 mm across, has formed in the recrystallised matrix and at FeTi oxide sites.

Mineral Mode (by volume): plagioclase (albite) 60%, actinolite 25%, biotite 6%, quartz 5%, FeTi oxide (includes magnetite) 3%, titanite 1% and traces of apatite and pyrite.

Interpretation and comment: It is interpreted that the sample is a biotite grade metamorphosed medium to coarse grained epiclastic sandstone, derived from a dacitic to andesitic source. There are abundant detrital grains of plagioclase, with lesser amounts of

quartz, lithics, ferromagnesian and FeTi oxide grains. There is only a minor matrix component and it has been completely recrystallised. The rock was largely replaced by a metamorphic assemblage (except for relict quartz, FeTi oxide and trace apatite grains) of albite and actinolite, with minor biotite, finely granular magnetite and a little titanite.

152838 TS

Summary: Metamorphosed medium to coarse grained lithic-crystal epiclastic sandstone, derived from a largely dacitic source. The rock contains abundant fine grained recrystallised lithic grains (probably felsic volcanic material including porphyritic types, as well as fine grained quartzofeldspathic siltstone), along with a lesser proportion of relict quartz and altered plagioclase grains, a few altered ferromagnesian grains and a little relict FeTi oxide (e.g. titanomagnetite) and apatite. A minor matrix component was interstitial to the detrital grains. The rock was metamorphosed, at least to biotite grade, with replacement of lithic material, plagioclase, ferromagnesian grains and the matrix by an assemblage of actinolite, quartz, albite and biotite, with minor magnetite, carbonate and titanite and a trace of epidote.

Handspecimen: The sample is composed of a massive, metamorphosed, coarse grained lithic-feldspathic-quartz volcaniclastic rock, e.g. a coarse epiclastic sandstone or tuff. Abundant lithic grains are up to several millimetres across, with minor quartz and feldspar grains. The rock shows considerable recrystallisation and development of grey-green metamorphic amphibole and dark brown biotite. Minor magnetite must be present, as the rock is strongly magnetic, with susceptibility up to 8220 x 10^{-5} SI units.

Petrographic description

a) Primary rock characteristics: In the section, the rock has a moderately preserved relict medium to coarse clastic texture. There are scattered relict grains of quartz up to 2.5 mm across (texturally they represent former volcanic phenocrysts), along with pseudomorphs after former plagioclase grains up to 2 mm across and after a few ferromagnesian grains, also up to 2 mm across. The rock contains abundant recrystallised lithic grains, now with diffuse boundaries and internal characteristics largely obscured by recrystallisation. However, it can be inferred that many of the lithic grains were originally of felsic volcanic type (some porphyritic), and others were fine grained quartzofeldspathic siltstone. There are also scattered relict grains of former igneous FeTi oxide (e.g. titanomagnetite) up to 0.9 mm across, a few grains of apatite up to 0.8 mm across and a trace of zircon. Interstitial to the detrital grains, there is a minor, recrystallised, finer grained matrix component. From the relict characteristics and bulk composition, the rock is interpreted as a medium to coarse grained lithic-crystal epiclastic sandstone, with a provenance from a dacitic volcanic source.

b) Alteration and structure: The original volcaniclastic rock was metamorphosed, with significant replacement and recrystallisation. All original plagioclase (as discrete grains and in lithic and matrix material), was replaced by fine to medium grained albite, accompanied in places by quartz, actinolite and minor biotite. Ferromagnesian grains, and much of the lithic grains and matrix, were replaced by fine to medium grained green actinolite and by biotite (the latter is only locally common), with a little carbonate, granular fine grained magnetite, titanite and trace epidote. Original phenocrystal quartz grains were commonly overgrown by quartz and locally replaced by actinolite. Igneous FeTi oxide is replaced by titanite to a minor extent. A weak foliation is present, defined by slight preferred orientation of altered lithic grains and by elongation of actinolite and biotite aggregates. A single discontinuous vein up to 2 mm wide and approximately parallel to foliation contains fine to medium grained actinolite, with minor granular magnetite and an aggregate of quartz. The metamorphic assemblage in the sample indicates that metamorphism attained at least biotite grade.

c) Mineralisation: The sample contains minor relict grains of former igneous FeTi oxide (titanomagnetite) up to 0.9 mm across. Minor finely granular magnetite has formed by metamorphism and is commonly associated with actinolite and biotite.

Mineral Mode (by volume): quartz 35%, albite 30%, actinolite 20%, biotite 8%, FeTi oxide/magnetite 4%, titanite and carbonate each 1% and traces of apatite, epidote and zircon.

Interpretation and comment: It is interpreted that the sample represents a biotite grade metamorphosed medium to coarse grained lithic-crystal epiclastic sandstone, derived from a

dacitic source. It contains abundant fine grained recrystallised lithic grains (felsic volcanic material and fine grained quartzofeldspathic siltstone), along with a lesser proportion of relict quartz and altered plagioclase grains, a few altered ferromagnesian grains and a little relict FeTi oxide (e.g. titanomagnetite) and apatite. A minor matrix component was interstitial to the detrital grains. Metamorphism caused replacement of lithic material, plagioclase, ferromagnesian grains and the matrix by an assemblage of actinolite, quartz, albite and biotite, with minor magnetite, carbonate and titanite and a trace of epidote.

152839 TS

Summary: Metamorphosed medium to coarse grained lithic-crystal epiclastic sandstone, or pyroclastic rock, derived from a felsic volcanic (e.g. dacitic) source. Relict textures are only moderately preserved due to imposed penetrative deformation and later metamorphic recrystallisation effects. The original rock contained abundant fine grained volcanic lithic, quartz and plagioclase grains and a finer grained matrix, with minor FeTi oxide and apatite grains. The rock was initially deformed, developing a weak foliation. There was subsequent metamorphic recrystallisation that developed a randomly oriented metamorphic assemblage that is dominated by quartz, albite and biotite, with subordinate actinolite. Minor magnetite and a little pyrite tend to be concentrated in biotite aggregates. Metamorphism has evidently achieved at least biotite grade.

Handspecimen: The sample is composed of a weakly foliated, medium to coarse grained metamorphosed lithic-feldspar-quartz volcaniclastic rock. Lithic grains are up to several millimetres across, with feldspar and quartz grains being smaller. Original matrix material has recrystallised and there is considerable replacement by dark brown-black biotite and grey-green amphibole. The foliation is defined by alignment of lithic grains. Minor magnetite must be present, as the rock is very strongly magnetic, with susceptibility up to 1140 x 10^{-4} SI units.

Petrographic description

a) Primary rock characteristics: In the section, relict texture is moderately preserved, although the rock was penetratively deformed and subsequently had a metamorphic overprint. There are scattered relict, originally volcanic phenocrystal grains of quartz up to 2.5 mm across. There were also scattered plagioclase grains up to 2 mm across and somewhat larger lithic grains (probably fine grained felsic volcanic material), but both of these components are strongly recrystallised. There are a few relict grains of formerly igneous FeTi oxide (e.g. titanomagnetite) up to 0.8 mm across and sparse, but conspicuous relict apatite grains up to 0.9 mm across, along with a trace of zircon. Original finer grained matrix material interstitial to the lithic, quartz and plagioclase grains was totally recrystallised. From the relict characteristics and bulk composition, it is interpreted that the rock represents a felsic volcanic composition (e.g. dacitic) coarse pyroclastic (tuff) or epiclastic.

b) Alteration and structure: The original volcaniclastic rock was penetratively deformed and subsequently metamorphosed, with considerable recrystallisation. A weak foliation was initially imposed, with alignment of lithic and plagioclase grains. It is speculated that there was an early, regional metamorphic assemblage that included sericite, chlorite, carbonate and albite. The later metamorphic overprint was static and formed a randomly oriented, new mineral assemblage. Quartz overgrowths occurred on some relict quartz and altered plagioclase grains. Lithics were replaced by fine grained aggregates of albite, quartz, biotite and actinolite (varying proportions) and plagioclase by fine grained albite and quartz, with minor actinolite. The original matrix was replaced by disseminations and abundant aggregates of fine grained biotite, with subordinate patchy actinolite, quartz and albite, with a trace of epidote in biotite aggregates. Metamorphic biotite is mostly brownish in colour, but a minor proportion is greenish. Finely granular magnetite is commonly disseminated in biotite aggregates and it also locally occurs with actinolite. Similarly, there is a little fine grained pyrite, occurring in aggregates up to 1 mm across, mostly hosted in biotite. The metamorphic assemblage in the sample indicates that metamorphism attained at least biotite grade.

c) Mineralisation: The sample contains a few relict grains of former igneous FeTi oxide (titanomagnetite) up to 0.8 mm across. Minor finely granular magnetite and a little pyrite formed by metamorphism and are commonly associated with biotite and actinolite. Pyrite aggregates are up to 1 mm across.

Mineral Mode (by volume): quartz and albite each 35%, biotite 20%, actinolite 5%, FeTi oxide/magnetite 3%, apatite and pyrite each 1% and traces of epidote and zircon.

Interpretation and comment: It is interpreted that the sample is a medium to coarse grained lithic-crystal epiclastic sandstone, or pyroclastic rock, derived from a felsic volcanic (e.g. dacitic) source that has experienced early penetrative deformation (foliation development) and subsequent static biotite grade metamorphosm. Relict textures are only moderately preserved, but it is apparent that there were abundant fine grained volcanic lithic, quartz and plagioclase grains and a finer grained matrix, with minor FeTi oxide and apatite grains. There was early deformation and subsequent metamorphic recrystallisation that developed a randomly oriented metamorphic assemblage that is dominated by quartz, albite and biotite, with subordinate actinolite. Minor magnetite and a little pyrite tend to be concentrated in biotite aggregates. Metamorphism has evidently achieved at least biotite grade.

152840a TS

Summary: Metamorphosed coarse lithic-crystal felsic tuff or epiclastic, with an early weak foliation overprinted by fine grained metamorphic recrystallisation. The rock was dominated by lithic fragments of fine grained, commonly porphyritic felsic volcanic rock which had a very fine grained (?aphanitic) groundmass and possible fluidal and/or vitriclastic texture, with a few quartz, plagioclase and ferromagnesian (probably biotite) phenocrysts. In-between the larger lithic fragments, there are smaller lithic grains and isolated disaggregated phenocrystal grains of quartz, plagioclase and minor ferromagnesian material. Weak foliation is defined by preferred orientation of the lithic fragments. The rock has been subsequently affected by metamorphism, with fine grained recrystallisation of lithic fragment groundmass material to quartz, albite, K-feldspar and biotite. There is also formation of fine grained biotite aggregates in the interstitial sites and at former ferromagnesian sites. A little actinolite, epidote and chlorite have formed as metamorphic minerals. The metamorphic assemblage is indicative of metamorphism to biotite grade.

Handspecimen: The sample is composed of a dark grey, coarsely fragmental rock, with apparent fine grained and locally porphyritic lithic fragments up to 1.5 cm across. There are also a few discrete quartz and feldspar grains up to a few millimetres across that resemble volcanic phenocrysts. The lithic fragments are rather tightly packed and only a minor amount of interstitial matrix occurs. The dark colour of the rock is likely to be due to the development of fine grained metamorphic biotite. The sample is essentially non-magnetic, with susceptibility of $<10 \times 10^{-5}$ SI units.

Petrographic description

a) Primary rock characteristics: In the section, relict texture is moderately preserved, but it is evident that the rock enjoyed mild penetrative deformation and subsequent metamorphic recrystallisation. The rock is dominated by medium to coarse grained lithic fragments, up to 1.5 cm across. These are fine grained, recrystallised, but with locally preserved possible fluidal or vitriclastic texture, as well as being porphyritic. Phenocryst phases in the fragments include quartz (up to 7 mm), (altered) plagioclase (up to 2 mm) and uncommon (altered) ferromagnesian grains (up to 3 mm across), along with trace microphenocrysts of apatite and zircon. Relict shapes of the pseudomorphs after ferromagnesian grains suggest that some could have been biotite. In-between the larger lithic fragments, there are smaller fragments and isolated (disaggregated) grains of quartz, plagioclase and ferromagnesian material in a finer grained, probably tuffaceous matrix. In the lithic fragments, the dominant fine grained (perhaps originally aphanitic) groundmass material was evidently of quartzofeldspathic composition. The relict characteristics of the rock indicate that it represents a coarse lithic-crystal felsic tuff (pyroclastic), or possibly an epiclastic, derived from a dacitic volcanic source.

b) Alteration and structure: The original volcaniclastic rock was weakly deformed, causing a weak foliation to develop, defined by preferred orientation of lithic fragments. The rock was later metamorphosed, with development of a fine grained metamorphic mineral assemblage. The fine grained groundmass material in lithic fragments was finely recrystallised to quartz, albite, K-feldspar and minor biotite, with a little epidote, actinolite and chlorite. Plagioclase phenocrysts were replaced by albite, K-feldspar and local quartz and biotite. Former ferromagnesian grains and much of the interstitial material were replaced by fine grained aggregates of khaki to greenish biotite, along with minor quartz, and a little actinolite, plus trace FeTi oxide, chlorite, epidote and pyrite. Adjacent to one relict quartz phenocryst, there are a couple of small aggregates of actinolite and epidote. The metamorphic assemblage in the sample indicates that metamorphism attained at least biotite grade.

c) Mineralisation: There is a trace of FeTi oxide and pyrite developed as very small grains in association with fine grained metamorphic biotite aggregates.

Mineral Mode (by volume): plagioclase (albite) 35%, quartz 30%, K-feldspar 20%, biotite 12%, actinolite and epidote each 1% and traces of FeTi oxide, apatite, chlorite, pyrite and zircon.

Interpretation and comment: It is interpreted that the sample represents a coarse lithic-crystal felsic tuff or epiclastic, with an early weak foliation overprinted by fine grained metamorphic recrystallisation that occurred at least at biotite grade. The rock contained abundant lithic fragments of fine grained, commonly porphyritic felsic volcanic rock with a very fine grained (?aphanitic) groundmass and possible fluidal and/or vitriclastic texture, plus quartz, plagioclase and ferromagnesian (probably biotite) phenocrysts. In-between the larger lithic fragments, there are smaller lithic grains and isolated phenocrystal grains of quartz, plagioclase and minor ferromagnesian material. Weak foliation is defined by preferred orientation of the lithic fragments. The rock was later affected by metamorphic recrystallisation of lithic fragment groundmass material to quartz, albite, K-feldspar and biotite. There is also formation of fine grained biotite aggregates in the interstitial sites and at former ferromagnesian sites. A little actinolite, epidote and chlorite have formed as metamorphic minerals.

152840b TS

Summary: Coarse grained felsic volcanic fragmental rock, e.g. lithic-crystal tuff, with evidence of imposed hydrothermal alteration and metamorphic effects. The original rock was dominated by coarse fragments of fine grained, locally fluidal texture, porphyritic felsic volcanic rock (e.g. of dacitic composition). The fragments contained phenocrysts of quartz, plagioclase and ferromagnesian material in a possibly aphanitic quartzofeldspathic groundmass. The rock also contains a few disaggregated phenocrystal grains of quartz, plagioclase and ferromagnesian material. Metamorphic effects are expressed by finely granular recrystallisation of groundmass material to albite, K-feldspar and quartz, with minor actinolite. There was replacement of plagioclase phenocrysts by K-feldspar, albite and minor quartz, carbonate, epidote and actinolite, with former ferromagnesian material being replaced mostly by actinolite, with minor biotite and a little carbonate and magnetite. Subsequently, most biotite was replaced by chlorite. The rock also contains traces of disseminated pyrite and chalcopyrite.

Handspecimen: The sample is composed of an altered, coarse lithic-crystal felsic fragmental volcanic rock. There are scattered grey-green altered fragments up to several millimetres across and pale pink-brown altered feldspar and grey quartz phenocrystal grains up to a few millimetres across, with a creamy to grey, fine grained quartzofeldspathic groundmass. The grey-green colour in the fragments could be due to replacement by chlorite and/or actinolite. A trace of fine grained pyrite is observed locally. The sample is weakly to moderately magnetic, with susceptibility up to 130 x 10^{-5} SI units. Staining of the section offcut with sodium cobaltinitrite showed that there is abundant K-feldspar in the groundmass.

Petrographic description

a) Primary rock characteristics: In the section, relict texture is moderately preserved. It is apparent that the rock was originally a coarse fragmental, with diffuse fragments up to 1 cm across of fine grained, locally fluidal textured, porphyritic felsic volcanic rock. These are relatively tightly packed, along with isolated discrete grains of quartz, altered plagioclase and altered ferromagnesian material. The porphyritic fragments contained phenocrysts of quartz up to 4 mm across, with smaller phenocrysts of plagioclase and ferromagnesian material in a former fine grained, perhaps aphanitic quartzofeldspathic groundmass (containing traces of disseminated apatite, FeTi oxide and zircon grains). Relict shapes after former ferromagnesian grains suggest that biotite was originally present, along with at least one other ferromagnesian phase. From the relict characteristics, the rock is interpreted as a coarse grained, lithic-crystal tuff, probably of dacitic composition.

b) Alteration and structure: The original volcaniclastic rock has experienced variable replacement by fine to medium grained metamorphic minerals, as well as possible effects of hydrothermal alteration (that could have occurred prior to metamorphic recrystallisation). Plagioclase phenocrysts were replaced by K-feldspar, and locally by albite and minor actinolite and quartz, along with a little carbonate and trace epidote. Former ferromagnesian grains were replaced mostly by actinolite, but some were replaced by fine grained metamorphic biotite; there was also minor quartz, epidote, titanite and carbonate at some sites. Subsequently, most biotite was retrogressed to chlorite. In the groundmass, there was total replacement by finely granular quartz, albite and K-feldspar, with minor actinolite and traces of pyrite and chalcopyrite. There are patchy replacement zones up to a few millimetres across in the groundmass of finely granular K-feldspar and also somewhat coarser aggregates of actinolite ± K-feldspar ± quartz ± carbonate. In actinolite-rich aggregates, there are a few disseminations of fine grained magnetite. There is evidence of slight supergene oxidation in the sample, expressed by local goethite replacement of pyrite and chalcopyrite. It can be implied from the relative abundance of K-feldspar and actinolite-rich replacement patches, that the rock experienced introduction of K, Ca, Fe and Mg prior to, or during, metamorphism. The metamorphic assemblage indicates that metamorphism attained at least biotite grade.

c) Mineralisation: There is a little sparsely disseminated pyrite in grains up to 0.6 mm across and rare chalcopyrite up to 0.1 mm across, as part of the alteration/n=metamorphic assemblage. Both sulphides are slightly altered to goethite. A trace of fine grained magnetite occurs with some actinolite-rich patches.

Mineral Mode (by volume): K-feldspar 35%, plagioclase (albite) and quartz each 25%, actinolite 12%, chlorite and carbonate each 1% and traces of FeTi oxide/magnetite, apatite, epidote, biotite, pyrite, chalcopyrite, goethite, titanite and zircon.

Interpretation and comment: It is interpreted that the sample is a metamorphosed and probably hydrothermally altered, coarse grained felsic volcanic fragmental rock, e.g. lithic-crystal tuff. It was dominated by coarse fragments of fine grained, locally fluidal texture, porphyritic felsic volcanic rock (e.g. of dacitic composition). The fragments contained phenocrysts of quartz, plagioclase and ferromagnesian material in a possibly aphanitic quartzofeldspathic groundmass. Metamorphism caused finely granular recrystallisation of groundmass material to albite, K-feldspar and quartz, with minor actinolite. There was replacement of plagioclase phenocrysts by K-feldspar, albite and minor quartz, carbonate, epidote and actinolite, with former ferromagnesian material being replaced mostly by actinolite, with minor biotite and a little carbonate and magnetite. Subsequently, most biotite was replaced by chlorite. The rock also contains traces of disseminated pyrite and chalcopyrite.

152841 TS

Summary: Metamorphosed, foliated fine grained porphyritic felsic volcanic rock, possibly ignimbritic in character. It is dominated by fine grained, altered felsic volcanic material, with a few elongate fiamme, now replaced largely by fine grained sericite. The dominant, originally aphanitic or glassy material contained scattered quartz phenocrysts along with a few microphenocrysts of FeTi oxide (titanomagnetite). Initially, the rock was subjected to weak deformation, causing development of a weak foliation. There was probably low grade regional metamorphism and/or hydrothermal alteration, causing replacement by fine grained quartz and abundant sericite, with minor albite. The rock was subsequently subjected to thermal metamorphism, resulting in development of disseminations and aggregates of fine grained biotite, with a little chlorite and magnetite.

Handspecimen: The sample is composed of a pale grey-green, weakly foliated, quartz-porphyritic felsic volcanic rock. There are a few elongate darker fragments of porphyritic felsic volcanic material up to 2 cm across that resemble coarse fragments (fiamme), enclosed in a more homogeneous matrix. The rock was probably replaced by fine grained quartz, sericite and chlorite and there must be a little magnetite as the sample is moderately magnetic, with susceptibility up to 930 x 10^{-5} SI units.

Petrographic description

a) Primary rock characteristics: In the section, relict texture is moderately preserved. There are scattered phenocrystal quartz grains up to 1.5 mm across and scattered fiamme-like elongate aggregates up to 2 cm across (mostly < a few millimetres). Some of the fiamme are porphyritic (quartz-phyric), but apart from the quartz grains, are completely altered. The majority of the rock is composed of a weakly foliated aggregate of altered vitriclastic material. Apart from the relict quartz phenocrysts, there are also a few relict microphenocrysts of FeTi oxide (e.g. titanomagnetite) up to 0.6 mm across, along with a trace of apatite and zircon. There could have been scattered small ferromagnesian grains, all completely altered. The relict characteristics are interpreted to indicate the rock represents a vitric-crystal felsic pyroclastic (perhaps ignimbritic).

b) Alteration and structure: The original felsic volcaniclastic rock developed a weak foliation. Although this could have developed as a depositional feature (i.e. ignimbrite foliation, with preferred orientation of fiamme and smaller vitriclastic material). It is possible that there was an early regional metamorphic tectonic overprint, causing strong development of fine grained, foliated masses of sericite (replacing fiamme and the fine grained groundmass), along with finely granular quartz and lesser amounts of albite. During the early stage of metamorphism and alteration, chlorite-rich aggregates are likely to have formed, including the replacement of any prior ferromagnesian phases. It is interpreted that the rock was then metamorphosed thermally, causing replacement of much of the chlorite and some sericite by fine grained aggregates of khaki-coloured biotite. Aggregates of biotite are up to a few millimetres across and locally contain a little fine grained magnetite and chlorite. Original igneous FeTi oxide grains were locally replaced by leucoxene. The rock is considered to have been metamorphosed to biotite grade.

c) Mineralisation: There are a few relict grains of former igneous FeTi oxide (e.g. titanomagnetite) up to 0.6 mm across, along with a little fine grained magnetite, enclosed in the metamorphic biotite aggregates.

Mineral Mode (by volume): quartz 50%, sericite 30%, albite 10%, biotite 8%, chlorite and FeTi oxide/magnetite each 1% and traces of apatite, leucoxene and zircon.

Interpretation and comment: It is interpreted that the sample represents a fine grained porphyritic felsic volcanic rock, possibly ignimbritic in character, that has undergone early deformation and alteration, followed by thermal metamorphism. It is dominated by fine grained, altered vitriclastic material, with a few elongate fiamme. The dominant, originally

aphanitic or glassy material contained scattered quartz phenocrysts along with a few microphenocrysts of FeTi oxide (titanomagnetite). Initially, the rock was subjected to weak deformation, causing development of a weak foliation, along with low grade regional metamorphism and/or hydrothermal alteration, resulting in an assemblage of fine grained quartz and abundant sericite, with minor albite. The rock was subsequently thermally metamorphosed, resulting in development of disseminations and aggregates of fine grained biotite, with a little chlorite and magnetite.

152842_TS

Summary: Lithic-crystal-vitric felsic tuff, or reworked epiclastic rock, with weakly developed foliation. It is dominated by former medium to coarse lithic grains of fine grained siltstone and felsic volcanic material, in a fine vitriclastic matrix. There are also scattered disaggregated former phenocrystal quartz grains. The rock experienced early strong alteration to patchy chlorite and sericite, along with finely granular quartz and albite. A few irregular patches and anastomosing veins were emplaced at the early stage and could have contained quartz, chlorite, sericite and magnetite. The rock was subsequently affected by a thermal metamorphic overprint that caused the patchy development of fine grained metamorphic biotite. Several sub-parallel quartz-rich veins were emplaced, containing fine to medium grained "epithermal-like" infill textures. Later, most magnetite was replaced by hematite and the rock slightly affected by supergene oxidation with development of patchy goethite staining.

Handspecimen: The sample is composed of a pale grey-green, fine to medium grained, strongly altered felsic volcaniclastic rock. It may be composed largely of altered lithic material, but there are a few discrete quartz grains (e.g. volcanic phenocrysts) up to 2 mm across. Alteration in the sample is probably to chlorite, sericite and quartz and there has been emplacement of a couple of milky quartz veins up to 3 mm wide. The rock is weakly to moderately magnetic, with susceptibility up to 150 x 10^{-5} SI units.

Petrographic description

a) Primary rock characteristics: In the section, relict texture is moderately preserved. The sample appears to contain abundant, rather diffuse, fine grained lithic grains up to a few millimetres across, ranging from angular to sub-rounded. The majority are composed of fine grained recrystallised sedimentary rock (e.g. siltstone, cherty argillite), but there is probably a subordinate population of fine grained felsic volcanic material (including quartz-phyric porphyritic fragments), along with discrete grains of former phenocrystal quartz up to 2 mm across. There are a few partly altered former igneous grains of FeTi oxide up to 0.3 mm across and a few "ghosted", completely altered, feldspar grains. The lithic and crystal components occurred in a fine grained matrix (generally subordinate in volume) of likely vitriclastic material, along with trace relict apatite and zircon. From the relict characteristics, the sample is interpreted as a rather coarse lithic-crystal-vitric felsic tuff, or reworked epiclastic.

b) Alteration and structure: The original felsic volcaniclastic rock may have had a weak primary depositional foliation, but was subsequently overprinted by hydrothermal alteration, a tectonic foliation, veining and metamorphic effects. Hydrothermal alteration is interpreted to have occurred, causing replacement of the rock by fine grained assemblages that varied from chlorite + quartz, to sericite + quartz + chlorite, with each containing minor albite (in granular intergrowth with quartz). A tectonic foliation is manifest in preferred orientation of sericite. During the early alteration it is likely that a few irregular veins and alteration patches up to 1.5 mm wide developed, containing quartz, chlorite, sericite and magnetite. Subsequently, the rock was overprinted by thermal metamorphic effects. This led to finely granular recrystallisation of most components and the growth of fine disseminations and irregular aggregates up to 2 mm across of khaki-coloured metamorphic biotite. There is a little magnetite and trace epidote associated with biotite. A few sub-parallel quartz-rich veins up to 2 mm wide were emplaced. These have extensional growth textures, with fine to medium grained granular to prismatic quartz ("epithermal-like") that has not been affected by tectonic overprinting and recrystallisation. Later, most magnetite (and igneous FeTi oxide) in the rock was replaced by hematite and the rock affected by supergene oxidation effects, causing patchy goethite staining (e.g. concentrated along the quartz veining).

c) Mineralisation: There are a few relict grains of former igneous FeTi oxide (e.g. titanomagnetite) up to 0.3 mm across, along with a little fine grained magnetite formed by metamorphism/alteration. These phases have been largely replaced by hematite.

Mineral Mode (by volume): quartz 50%, chlorite 20%, sericite 12%, albite 10%, biotite 5%, hematite and goethite each 1% and traces of epidote, apatite, FeTi oxide/magnetite and zircon.

Interpretation and comment: It is interpreted that the sample is a rather coarse lithic-crystal-vitric felsic tuff, or reworked epiclastic rock. It is dominated by former medium to coarse lithic grains of fine grained siltstone and felsic volcanic material, in a fine vitriclastic matrix. There are also scattered former phenocrystal quartz grains. The rock experienced early strong alteration to chlorite, sericite, finely granular quartz and albite. A few irregular patches and anastomosing veins were emplaced at the early stage with quartz, chlorite, sericite and magnetite. The rock was subsequently affected by a thermal metamorphic overprint that caused biotite replacement of some chlorite and sericite. Several sub-parallel quartz-rich "epithermal-like" veins were emplaced. Most magnetite was later replaced by hematite and the rock affected by supergene oxidation with development of patchy goethite staining.

152843 TS

Summary: Lithic-crystal felsic tuff, or reworked epiclastic rock that has undergone initial strong hydrothermal alteration, with imposed weak foliation and a subsequent thermal metamorphic overprint. The rock contains abundant altered felsic volcanic lithic fragments, perhaps of vitriclastic and pumiceous material, with some being sparsely porphyritic. The fragments include "fiamme-like" elongate aggregates. There is also a subordinate population of relict phenocrystal quartz grains, along with a few altered ferromagnesian and feldspar grains and a little FeTi oxide. It is likely that hydrothermal alteration caused strong replacement by an assemblage of quartz, sericite and chlorite, with the layer silicates being concentrated into the fiamme-like aggregates and their preferred orientation defining a weak foliation. Later metamorphism caused the formation of minor randomly oriented biotite, mostly in the fiamme-like aggregates and at former ferromagnesian grain sites. Slight weathering effects have caused goethite staining and fracture-controlled veinlike masses.

Handspecimen: The sample is composed of a slightly weathered, grey-green, medium to coarse grained, lithic-crystal felsic tuff or epiclastic. The rock contains scattered chlorite-altered lithic (maybe pumiceous) fragments up to several millimetres across. Some of these are elongate and "fiamme-like". There are a few relict phenocrystal grains of quartz up to 3 mm across and altered feldspar and FeTi oxide grains (the latter replaced by hematite). The rock is strongly altered, with replacement by weakly foliated sericite, chlorite and quartz. Later weathering has caused orange-brown goethite staining, especially on foliation-parallel fractures. The rock is moderately magnetic, with susceptibility up to 170 x 10^{-5} SI units.

Petrographic description

a) Primary rock characteristics: In the section, relict texture is moderately preserved. Much of the rock appears to have been composed of abundant lithic fragments of fine grained felsic volcanic material, possibly vitriclastic and/or pumiceous, with scattered elongate "fiamme-like " altered aggregates up to several millimetres that could represent flattened pumice fragments. There are scattered relict phenocrystal grains of quartz up to 2 mm across, a few pseudomorphs after former ferromagnesian grains (that included biotite) up to 2 mm across, and small "ghosted" pseudomorphs after former feldspar grains. The rock has sparsely scattered, partly altered microphenocrysts of FeTi oxide (e.g. titanomagnetite) up to 0.7 mm across and a trace of zircon. From the relict characteristics, the rock is interpreted as a felsic lithic-crystal tuff. Textures are not diagnostic as to whether it was reworked to form an epiclastic.

b) Alteration and structure: The original volcaniclastic rock underwent hydrothermal alteration, weak deformation and subsequent thermal metamorphism. There was initial strong hydrothermal alteration, causing replacement of the rock by abundant finely granular quartz, with subordinate sericite and chlorite. The latter phases are concentrated at many lithic grain sites (especially the fiamme-like aggregates) and at altered ferromagnesian grain sites, along with a trace of leucoxene. A weak foliation has formed, defined by preferred orientation of the layer silicates, and by elongation of altered fragments. The interpreted thermal metamorphic overprint has caused partial replacement of chlorite and sericite by disseminations and aggregates of fine grained khaki-coloured biotite showing random orientation. A little epidote occurs in the biotite aggregates. The presence of significant biotite indicates that metamorphism must have achieved biotite grade. Most igneous FeTi oxide was replaced by hematite and later weathering effects caused patchy goethite staining and local concentration of goethite along late, foliation-parallel fractures.

c) Mineralisation: Grains of former igneous FeTi oxide (e.g. titanomagnetite) were up to 0.7 mm across and were later largely replaced by hematite.

Mineral Mode (by volume): quartz 55%, sericite 20%, chlorite 12%, biotite 5%, hematite and goethite each 1% and traces of epidote, FeTi oxide, leucoxene and zircon.

Interpretation and comment: It is interpreted that the sample represents a felsic lithic-crystal tuff, or reworked epiclastic that has experienced strong hydrothermal alteration, with imposed weak foliation and a subsequent thermal metamorphic overprint to biotite grade. The rock contains abundant altered felsic volcanic lithic fragments, perhaps of vitriclastic and pumiceous material, including "fiamme-like" elongate aggregates. There is also a subordinate population of relict phenocrystal quartz grains, along with a few altered ferromagnesian and feldspar grains and a little FeTi oxide. Hydrothermal alteration caused strong replacement by an assemblage of quartz, sericite and chlorite, with the layer silicates being concentrated into the fiamme-like aggregates and their preferred orientation defining a weak foliation. Later metamorphism caused the formation of minor randomly oriented biotite, mostly in the fiamme-like aggregates and at former ferromagnesian grain sites. Slight weathering effects have caused goethite staining and thin aggregates to form.

152845 TS

Summary: Felsic vitric-crystal tuff, possibly ignimbritic, originally containing abundant fine vitriclastic material as well as larger pumiceous fragments, scattered relict quartz phenocrysts and a few altered phenocrystal grains of ferromagnesian phases, feldspar and FeTi oxide. The rock probably experienced initial hydrothermal alteration, with replacement by a fine grained assemblage of quartz, sericite and chlorite. Subsequently, a thermal metamorphic event might have destroyed chlorite and formed widespread fine grained biotite, concentrated at former ferromagnesian and some of the vitriclastic fragment sites.

Handspecimen: The sample is composed of a weakly to moderately foliated, strongly altered coarse felsic pyroclastic rock. It contains scattered grey-green, irregular to elongate, locally fiamme-like altered volcanic fragments (perhaps originally pumiceous) up to 1.5 cm across, and a few phenocrystal grains of quartz up to 3 mm across, in a finer grained pale grey-green tuffaceous matrix. It is likely that the rock has sericite-chlorite-quartz alteration, although the dark colour of some fragments could imply the presence of fine grained metamorphic biotite. The rock is very weakly magnetic, with susceptibility up to 40 x 10^{-5} SI units.

Petrographic description

a) Primary rock characteristics: In the section, relict texture is moderately preserved, but it is evident that the rock is hydrothermally altered, deformed and with indications that there was a later thermal metamorphic overprint. There are scattered relict phenocrystal grains of quartz up to 3.5 mm across and pseudomorphs after a few former grains of ferromagnesian phases up to 2 mm across (maybe biotite and pyroxene originally), and after a few smaller grains of feldspar. The remainder of the rock was dominated by fine grained vitriclastic material, with scattered larger elongate pumiceous fragments (some of which are fiamme-like and up to several millimetres across). There are also a few altered grains of former igneous FeTi oxide up to 0.5 mm across and a trace of relict zircon. The relict features indicate that the rock was a vitric-crystal felsic tuff, possibly ignimbritic in character.

b) Alteration and structure: The original pyroclastic rock was hydrothermally altered, deformed and later thermally metamorphosed. The initial alteration assemblage was dominated by fine grained quartz and sericite, probably with subordinate chlorite and a trace of leucoxene at former ferromagnesian sites. The layer silicates were commonly concentrated into some of the fiamme-like fragments. A moderate tectonic foliation was then imposed, defined by preferred orientation of sericite and locally wrapping around relict quartz phenocrysts, causing "pressure shadow" texture. The thermal metamorphic overprint is indicated by widespread development of fine grained disseminations and aggregates of khaki-coloured biotite. This has probably replaced former chlorite (as well as some sericite) and is concentrated at some vitriclastic fragment, former ferromagnesian and feldspar sites (commonly intergrown with sericite). All former igneous FeTi oxide was replaced by hematite. A single discontinuous vein of muscovite up to 0.5 mm wide cut across the foliation at a high angle. It has been the site for later deposition of minor supergene goethite.

c) Mineralisation: Grains of former igneous FeTi oxide (e.g. titanomagnetite) were up to 0.5 mm across and were later replaced by hematite.

Mineral Mode (by volume): quartz 55%, sericite 35%, biotite 9%, hematite 1% and traces of goethite, leucoxene and zircon.

Interpretation and comment: It is interpreted that the sample is a metamorphosed and deformed felsic vitric-crystal tuff, possibly ignimbritic. It was dominated by fine vitriclastic material as well as larger pumiceous fragments, scattered relict quartz phenocrysts and a few altered phenocrystal grains of ferromagnesian phases, feldspar and FeTi oxide. The rock probably experienced initial hydrothermal alteration, with replacement by a fine grained assemblage of quartz, sericite and chlorite. Subsequently, a thermal metamorphic event destroyed chlorite and formed widespread fine grained biotite, concentrated at former

ferromagnesian and some of the vitriclastic fragment sites. The occurrence of biotite indicates that thermal metamorphism attained at least biotite grade.

152846 TS

Summary: Metamorphosed, hydrothermally altered porphyritic felsic volcanic rock, perhaps originally of dacitic composition. The rock retains relict quartz phenocrysts and would have contained scattered phenocrysts of ferromagnesian material (probably biotite mostly) and a few of feldspar. The groundmass was fine grained (perhaps aphanitic), with relict fluidal texture and was of quartzofeldspathic composition. There is no diagnostic relict textural evidence that the rock was originally epiclastic or pyroclastic in character. It is interpreted that there was initial strong hydrothermal alteration, with replacement of the rock by quartz, sericite and subordinate chlorite. Weak deformation was imposed, leading to a weak foliation being expressed in sericite-rich zones. Subsequent thermal metamorphism led to crystallisation of fine grained biotite and a little magnetite throughout, but concentrated at former ferromagnesian sites. The rock is also cut by a few veins of quartz, with a little biotite, epidote and magnetite.

Handspecimen: The sample is composed of a relatively massive, dark grey altered felsic volcanic rock. It has a porphyritic texture, with scattered quartz phenocrysts up to 3 mm across and dark pseudomorphs after other former phenocryst phases, e.g. ferromagnesian and feldspar minerals, in a fine grained altered groundmass. The rock probably has alteration to fine grained sericite, chlorite and quartz, but its dark colour suggests that fine grained metamorphic biotite has developed. A little magnetite must occur, as the rock is moderately magnetic, with susceptibility up to 970 x 10^{-5} SI units.

Petrographic description

a) Primary rock characteristics: In the section, relict porphyritic texture is moderately well preserved. There are scattered relict quartz phenocrysts up to 3 mm across and pseudomorphs after former ferromagnesian phenocrysts and less common blocky feldspar phenocrysts up to 2 mm across Relict shapes of the ferromagnesian phenocrysts suggest that biotite was the main phase. The rock also contains a few partly altered FeTi oxide (e.g. titanomagnetite) microphenocrysts up to 0.5 mm across and a trace of relict apatite and zircon. The phenocrystal phases occurred in a fine grained (perhaps aphanitic), weakly fluidal texture quartzofeldspathic groundmass. The groundmass is largely homogeneous and there is no definitive evidence that the rock was originally of epiclastic or pyroclastic type. Consequently, it is interpreted that the rock was originally a porphyritic felsic volcanic, maybe of dacitic composition.

b) Alteration and structure: The original volcanic rock was hydrothermally altered, weakly deformed and later thermally metamorphosed. All original feldspar and ferromagnesian phenocrysts, along with the groundmass, were completed replaced. It is likely that the initial alteration assemblage was dominated by fine to medium grained quartz (in the replaced groundmass), along with abundant fine grained sericite, and subordinate chlorite. A weak foliation developed in zones in which sericite was mostly strongly developed. A thermal metamorphic overprint caused pervasive development of fine grained, khaki-coloured biotite, such that former feldspar phenocrysts were pseudomorphed by sericite + biotite, and ferromagnesian phenocrysts by sericite/muscovite, biotite and local chlorite, quartz, epidote and magnetite. In the altered groundmass, minor fine grained biotite and granular magnetite have formed. A couple of anastomosing, discontinuous veins up to 0.8 mm wide were emplaced. These are quartz-rich, but with minor biotite and a little magnetite and epidote. Retrograde alteration of igneous FeTi oxide and metamorphic magnetite caused partial replacement of these phases by hematite.

c) Mineralisation: Grains of igneous FeTi oxide (e.g. titanomagnetite) are up to 0.5 mm across. They, and the finely granular dispersed and vein-hosted metamorphic magnetite, have been partly replaced by retrograde hematite.

Mineral Mode (by volume): quartz 55%, sericite (-muscovite) 30%, biotite and chlorite each 6%, hematite and FeTi oxide each 1% and traces of epidote, apatite and zircon.

Interpretation and comment: It is interpreted that the sample is a porphyritic felsic volcanic rock, perhaps originally of dacitic composition, that has experienced hydrothermal alteration, weak deformation and later thermal metamorphism that attained biotite grade. There are relict quartz phenocrysts and pseudomorphs after scattered phenocrysts of ferromagnesian material (probably biotite mostly) and a few of feldspar. The groundmass was fine grained (perhaps aphanitic), with relict fluidal texture and was of quartzofeldspathic composition. There is no relict textural evidence that the rock was originally an epiclastic or pyroclastic. There was initial strong hydrothermal alteration, with replacement of the rock by quartz, sericite and subordinate chlorite. Deformation caused a weak foliation to develop in sericite-rich zones. Subsequent thermal metamorphism led to crystallisation of fine grained biotite and a little magnetite throughout, but concentrated at former ferromagnesian sites. The rock is also cut by a few veins of quartz, with a little biotite, epidote and magnetite.

152847 TS

Summary: Porphyritic felsic volcanic rock, with relict quartz phenocrysts and altered former phenocrystal grains of feldspar, ferromagnesian material (probably biotite) and a little FeTi oxide, in a formerly fine grained quartzofeldspathic groundmass. Although relatively homogeneous, the groundmass does show possible fragmental (and fine vitriclastic) texture in places, implying that the rock might have originally been ignimbritic. Strong hydrothermal alteration is implied, with replacement of the original rock by fine grained quartz, sericite and chlorite, with trace leucoxene. Original FeTi oxide grains were mostly replaced by hematite and leucoxene. A weak to moderate foliation prevails, defined by preferred orientation of layer silicates and altered feldspar grains and altered fragments. A possible metamorphic overprint is reflected in the incipient formation of fine grained biotite and magnetite, with most magnetite being replaced by hematite. A couple of anastomosing quartz veins were emplaced, mostly parallel to foliation. Weathering effects are manifest by patchy goethite development, especially along foliation planes.

Handspecimen: The sample is composed of a green-grey, fine grained altered porphyritic felsic volcanic rock, It is massive to weakly foliated, with a few relict phenocrysts of quartz up to 3 mm across and a few pseudomorphs after other former phenocryst phases (maybe feldspar, ferromagnesian material) up to a few millimetres across. The rock is probably strongly altered to fine grained quartz, sericite and chlorite. Slight weathering effects have caused minor orange-brown goethite staining, outlining weak foliation places. The sample is weakly magnetic, with susceptibility up to 100 x 10^{-5} SI units.

Petrographic description

a) Primary rock characteristics: In the section, relict porphyritic texture is moderately well preserved. There are a few relict quartz phenocrysts up to 2.5 mm across and pseudomorphs after former scattered phenocrysts of feldspar (up to 3 mm) and ferromagnesian material (up to 4 mm), along with a few altered microphenocrysts of FeTi oxide up to 0.9 mm across and traces of relict apatite and zircon. Relict shapes suggest that some of the ferromagnesian phenocrysts were biotite. The phenocrystal phases occurred in a fine grained (perhaps aphanitic) quartzofeldspathic groundmass that may have vaguely preserved flow foliation. The groundmass is relatively homogeneous, but there are possible pseudomorphs after elongate lithic aggregates up to several millimetres across, as well as possible fine vitriclastic texture. There do not seem to be any textural criteria to suggest that the rock was originally an epiclastic sandstone, but the relict features are more consistent with the rock representing a former felsic pyroclastic, e.g. ignimbrite of biotite dacite composition.

b) Alteration and structure: It is interpreted that the original felsic volcanic rock experienced strong pervasive hydrothermal alteration, with subsequently imposed penetrative deformation and possible incipient biotite grade thermal metamorphism. The groundmass was replaced by fine grained quartz, sericite and chlorite, with feldspar grains and the possible lithic fragments being replaced mostly by sericite, with minor chlorite and quartz. Ferromagnesian grains were replaced by sericite, chlorite, quartz and leucoxene, with FeTi oxide being largely altered to hematite and leucoxene. Deformation caused a weak to moderate foliation to develop, defined by preferred orientation of the layer silicates and by elongation of altered feldspar and lithic grains. Incipient thermal metamorphism is manifest in the local development of a little fine grained biotite at some former feldspar and ferromagnesian sites and by a little finely granular magnetite at ferromagnesian sites and in the groundmass. Most magnetite was later replaced by hematite. The altered rock contains a couple of anastomosing quartz veins up to 0.5 mm wide, largely parallel to foliation. Minor weathering effects are observed, with goethite staining in places, locally concentrated along fractures parallel to foliation.

c) Mineralisation: The rock contained a few grains of igneous FeTi oxide (e.g. titanomagnetite) up to 0.9 mm across. They, and traces of finely granular metamorphic magnetite, have been largely replaced by retrograde hematite ± leucoxene.

Mineral Mode (by volume): quartz 50%, sericite 25%, chlorite 22%, hematite and goethite each 1% and traces of biotite, FeTi oxide, apatite and zircon.

Interpretation and comment: It is interpreted that the sample represents a possibly ignimbritic, porphyritic felsic volcanic rock, containing relict quartz phenocrysts and altered former phenocrystal grains of feldspar, ferromagnesian material (probably biotite) and a little FeTi oxide, in a formerly fine grained quartzofeldspathic groundmass, with a few possible fragments. Strong hydrothermal alteration occurred, causing replacement by fine grained quartz, sericite and chlorite, with and little hematite and trace leucoxene. A weak to moderate foliation prevails, defined by preferred orientation of layer silicates and altered feldspar grains and altered fragments. A possible metamorphic overprint caused incipient formation of fine grained biotite and magnetite, with most magnetite being later replaced by hematite. A couple of anastomosing quartz veins were emplaced, mostly parallel to foliation. Weathering effects are manifest by patchy goethite development, especially along foliation planes.

152848 TS

Summary: Hydrothermally altered, deformed and metamorphosed porphyritic felsic volcanic rock, possibly a type of ignimbrite originally. It contained scattered phenocrysts of quartz, along with possible elongate lithic/vitric fragments and phenocrystal grains of ferromagnesian phases, feldspars and trace FeTi oxide. The groundmass appears to have been composed of fine vitriclastic material and displays a possible weak primary foliation. Hydrothermal alteration caused replacement of much of the rock by fine grained quartz and subordinate sericite and chlorite, along with development of a few replacive quartz aggregates in the groundmass. Later thermal metamorphism led to further recrystallisation, and concentrations of fine grained biotite, sericite, chlorite and a little magnetite and tourmaline at former lithic/vitric fragment, ferromagnesian and feldspar phenocryst sites. There was later replacement of igneous FeTi oxide and metamorphic magnetite by hematite. Weathering effects caused considerable goethite impregnation.

Handspecimen: The sample is composed of a strongly altered, pale grey-green, porphyritic and fragmental felsic volcanic rock, possibly of ignimbritic character. It contains scattered relict quartz phenocrysts up to 4 mm across, in a weakly foliated, fine grained altered quartzofeldspathic groundmass that contained scattered elongate wispy lithic/vitric fragments up to several millimetres across. It is likely that the rock was strongly altered to quartz and sericite, with minor chlorite. Minor weathering effects have caused orange-brown goethite to develop, in places outlining foliation planes. The sample is weakly magnetic, with susceptibility up to 70 x 10^{-5} SI units.

Petrographic description

a) Primary rock characteristics: In the section, relict porphyritic texture is moderately preserved. There are scattered relict quartz phenocrysts up to 5 mm across. Other irregular to elongate pseudomorphic aggregates up to several millimetres across are present, but relict textures are not diagnostic as to whether they include lithic/vitric fragments, and/or former ferromagnesian and feldspar phenocrysts. The rock retains a few altered microphenocrysts of FeTi oxide up to 0.8 mm across and a trace of relict zircon. A fine grained groundmass comprises about 70% of the sample and in places it has vague preservation of fine grained vitriclastic texture, despite alteration and recrystallisation The groundmass also displays a weak flow foliation locally and hence the rock is tentatively interpreted as a vitric-crystal felsic tuff, probably ignimbritic.

b) Alteration and structure: The original felsic volcanic rock was strongly hydrothermally altered, deformed and subsequently thermally metamorphosed. It is interpreted that the initial alteration assemblage affected the pseudomorphic aggregates and groundmass, with replacement by fine grained quartz, sericite and chlorite (with chlorite more abundant at many of the pseudomorphic aggregates sites). This assemblage was then deformed, with development of a weak to moderate, sericite-defined foliation, with many of the pseudomorphic aggregates also being elongate in the plane of the foliation. In the groundmass, a few aggregates of recrystallised fine to medium grained quartz up to 3 mm across developed. The thermal metamorphic event would have attained biotite grade and caused considerable recrystallisation of the pseudomorphic aggregates, replacing them by fine grained aggregates containing one or more of biotite, sericite, chlorite and a little granular magnetite and a few grains of blue tourmaline. Later, there was retrograde alteration of igneous FeTi oxide and much of the metamorphic magnetite to hematite. The rock was later subjected to weathering, with considerable goethite being deposited, especially at the pseudomorphic aggregates sites (i.e. impregnating biotite, sericite and chlorite).

c) Mineralisation: A few grains of igneous FeTi oxide occurred and a little granular magnetite formed at the pseudomorphic aggregates sites during metamorphism. These phases were later largely replaced by hematite.

Mineral Mode (by volume): quartz 65%, sericite 23%, chlorite 5%, biotite and goethite each 3%, hematite 1% and traces of FeTi oxide, tourmaline and zircon.

Interpretation and comment: It is interpreted that the sample is a metamorphosed, hydrothermally altered and deformed porphyritic felsic volcanic rock, of ignimbritic character. It contained scattered phenocrysts of quartz, along with elongate pseudomorphic aggregates after lithic/vitric fragments, and phenocrystal grains of ferromagnesian phases, feldspars and trace FeTi oxide. The groundmass was composed of fine vitriclastic material and displays a possible weak primary foliation. Hydrothermal alteration caused replacement of much of the rock by fine grained quartz and subordinate sericite and chlorite, along with development of a few replacive quartz aggregates in the groundmass. Later thermal metamorphism led to further recrystallisation, and concentrations of fine grained biotite, sericite, chlorite and a little magnetite and tourmaline at former lithic/vitric fragment, ferromagnesian and feldspar phenocryst sites. There was later replacement of igneous FeTi oxide and metamorphic magnetite by hematite. Weathering effects caused considerable goethite impregnation.

152849 TS

Summary: Felsic vitric-crystal tuff, possibly ignimbritic, with strong hydrothermal alteration effects, deformation and a later imposed thermal metamorphic overprint. The rock originally contained a few large quartz phenocrysts, along with possible phenocrysts of feldspar, ferromagnesian material and a few grains of FeTi oxide, as well as possible lithic/vitric fragments. The groundmass was fine grained, of quartzofeldspathic composition and contained vitriclastic material, with vague flow foliation. Alteration caused replacement of the rock by fine grained sericite, quartz and chlorite, and a subsequent moderate foliation was imposed by deformation. Later, the thermal metamorphic effect led to growth of fine grained biotite, largely at former ferromagnesian and lithic grain sites. Weathering effects were responsible for patchy goethite impregnation.

Handspecimen: The sample is composed of a weakly to moderately foliated, strongly altered, pale grey-green porphyritic felsic volcanic rock containing scattered relict quartz phenocrysts up to 6 mm across. There are other darker pseudomorphic aggregates up to a few millimetres across that could be after lithic grains and feldspar and ferromagnesian phenocrysts. The rock was altered to fine grained sericite, chlorite and quartz, with preferred orientation of the layer silicates defining the foliation. Slight weathering effects have caused patchy orange-brown goethite staining. The sample is weakly magnetic, with susceptibility up to 65 x 10^{-5} SI units.

Petrographic description

a) Primary rock characteristics: In the section, relict porphyritic texture is moderately preserved. The rock contains sparse scattered relict quartz phenocrysts up to 4.5 mm across as well as pseudomorphic aggregates up to a few millimetres across after other components that could have included former ferromagnesian (e.g. biotite) and feldspar phenocrysts, and elongate lithic/vitric fragments. There are also a few altered FeTi oxide grains up to 1 mm across. The fine grained groundmass of the rock occupies about 70% and was evidently of quartzofeldspathic composition. It retains vaguely preserved relict fine vitriclastic and fluidal texture and consequently, the rock is tentatively interpreted as a vitric-crystal felsic tuff, perhaps ignimbritic in character.

b) Alteration and structure: The original felsic volcanic rock was strongly hydrothermally altered, deformed and later affected by thermal metamorphism. It is likely that hydrothermal alteration caused replacement of the rock (except for relict quartz phenocrysts) by fine grained sericite, quartz and chlorite, with traces of leucoxene at former ferromagnesian sites (where there were also concentrations of chlorite). One or two pseudomorphic shapes, evidently after feldspar, are sericite-rich. A moderate foliation was imposed, defined by preferred orientation of the layer silicates and being most strongly expressed in the altered groundmass, where it locally wraps around the quartz phenocrysts. The effects of thermal metamorphism are indicated by minor development of fine grained khaki coloured biotite, with random orientation, mostly at the pseudomorphic aggregates sites and to a lesser extent in the altered groundmass. Igneous FeTi oxide grains were largely replaced by hematite and later weathering effects caused patchy goethite impregnation, especially of the pseudomorphic aggregates sites.

c) Mineralisation: A few grains of igneous FeTi oxide up to 1 mm across were originally present, but most were later altered to hematite.

Mineral Mode (by volume): sericite 50%, quartz 30%, chlorite 13%, biotite 5%, goethite and hematite each 1% and traces of FeTi oxide and leucoxene.

Interpretation and comment: It is interpreted that the sample represents a hydrothermally altered, deformed and subsequently thermally metamorphosed, felsic vitric-crystal tuff, possibly ignimbritic. It contained a few large quartz phenocrysts, along with possible phenocrysts of feldspar, ferromagnesian material and a few grains of FeTi oxide, as well as possible lithic/vitric fragments. The groundmass was fine grained, of quartzofeldspathic

composition and contained vitriclastic material, with vague flow foliation. Alteration caused replacement of the rock by fine grained sericite, quartz and chlorite, with a moderate foliation developing during deformation. Later, the thermal metamorphic effect led to growth of fine grained biotite, largely at former ferromagnesian and lithic grain sites. Weathering effects were responsible for patchy goethite impregnation.

152850 TS

Summary: Strongly hydrothermally altered, deformed and subsequently thermally metamorphosed vitric-crystal felsic tuff, probably of ignimbritic character. The rock retains scattered large relict quartz phenocrysts and clusters of phenocrysts, and has a few pseudomorphs after former possible ferromagnesian and feldspar phenocrysts. The original groundmass was quartzofeldspathic, with local pumiceous aggregates and fine vitriclastic material. Alteration caused replacement of the rock (except quartz phenocrysts) by fine grained sericite and minor quartz and chlorite. A moderate foliation was also imposed, defined by preferred orientation of the layer silicates and there was also local fracturing and recrystallisation of the quartz phenocrysts. Thermal metamorphism led to development of minor fine grained, randomly oriented biotite. Slight weathering effects were later imposed, resulting in patchy goethite impregnations.

Handspecimen: The sample is composed of a strongly altered, moderately foliated, coarsely porphyritic felsic volcanic rock. It contains scattered large phenocrystal grains and clusters of quartz up to 1 cm across, in a fine grained altered and foliated, pale to medium grey groundmass that appears to be sericite-rich. Slight weathering has affected the sample, with local goethite staining, mainly on foliation planes. The sample is essentially non-magnetic, with susceptibility of $<10 \times 10^{-5}$ SI units.

Petrographic description

a) Primary rock characteristics: In the section, relict porphyritic texture is moderately preserved. There are scattered relict quartz phenocrysts, with individual grains up to 6 mm across, and clusters of grains up to 1 cm across. There would have been a few other phenocrysts phases (e.g. feldspar, ferromagnesian material), but if so, they were completely altered and replaced by diffuse pseudomorphic aggregates. The groundmass of the rock is deformed (foliated) and finely recrystallised, but in a few places (e.g. adjacent to relict quartz phenocrysts), there is preservation of relict pumiceous and fine grained vitriclastic texture, along with possible flow foliation. A trace of fine grained relict zircon is enclosed in the altered groundmass. The relict features suggest that the original rock was a vitric-crystal felsic tuff, probably of ignimbritic character.

b) Alteration and structure: Strong hydrothermal alteration and subsequent deformation and thermal metamorphism affected the original rock. It is interpreted that there was complete replacement of any feldspar and ferromagnesian phases and the groundmass, mostly by fine grained sericite, with minor chlorite and quartz, and traces of leucoxene, locally in thin, elongate aggregates. At possible former ferromagnesian sites, there was increased chlorite and leucoxene content. Deformation caused the development of a moderate foliation, defined by preferred orientation of the layer silicates, commonly wrapping around relict quartz phenocrysts. Some phenocrysts also show local deformation effects, with strain, fracturing and local recrystallisation phenomena. Thermal metamorphic effects are manifest by development of minor disseminations and aggregates of fine grained khaki-coloured, randomly oriented biotite. Much of the groundmass sericite was also recrystallised to randomly oriented aggregates, overprinting the earlier foliation. Slight weathering effects imposed on the rock are indicated by patchy goethite staining and local concentrations along foliation-parallel fractures.

c) Mineralisation: No sulphides or primary oxide minerals were observed.

Mineral Mode (by volume): sericite 45%, quartz 40%, biotite 8%, chlorite 6%, goethite 1% and traces of zircon and leucoxene.

Interpretation and comment: It is interpreted that the sample is a felsic vitric-crystal tuff (maybe ignimbritic), showing strong hydrothermal alteration, deformation and later thermal metamorphic effects. It has scattered relict quartz phenocrysts and clusters of phenocrysts, and a few pseudomorphs after former possible ferromagnesian and feldspar phenocrysts.

The original groundmass had pumiceous aggregates and fine vitriclastic material. Alteration caused replacement of the rock (except quartz phenocrysts) by fine grained sericite and minor quartz and chlorite. A moderate foliation was also imposed, defined by preferred orientation of the layer silicates and there was also minor deformation of the quartz phenocrysts. Thermal metamorphism caused minor fine grained, randomly oriented biotite to form. Slight weathering effects were later imposed, resulting in patchy goethite impregnations.

152851 TS

Summary: Weathered felsic vitric-crystal tuff (possibly ignimbritic). The rock retains scattered relict phenocrystal grains of quartz, but other phenocrystal grains of feldspar and ferromagnesian material, plus lithic/vitric are completely altered. The original groundmass was fine grained and possibly dominated by vitriclastic material. Hydrothermal alteration caused replacement of the rock by fine grained quartz and sericite, with minor chlorite. A weak anastomosing foliation was imposed and it is likely that there was a subsequent thermal metamorphic overprint, developing a little fine grained biotite, mainly at pseudomorphic aggregates sites. Weathering led to significant degradation of chlorite and biotite to nontronite and the formation of goethite impregnations.

Handspecimen: The sample is composed of a weathered, weakly foliated, pale orange-brown to pale grey felsic tuff. It contains a few relict quartz grains (perhaps former phenocrysts) up to 2 mm across and altered grains that could represent former feldspar, ferromagnesian and lithic material. The rock has experienced strong alteration to fine grained sericite and quartz, with a later weathering overprint of clay and goethite. The sample is essentially non-magnetic, with susceptibility of $<10 \times 10^{-5}$ SI units.

Petrographic description

a) Primary rock characteristics: In the section, relict texture is moderately preserved. The rock appears to represent a felsic volcaniclastic, with scattered relict phenocrystal grains of quartz up to 1.5 mm across, scattered pseudomorphic aggregates after other phenocryst phases (e.g. feldspar, ferromagnesian material) and possible lithic/vitric fragments up to a few millimetres across, set in a fine grained vitriclastic groundmass that locally preserves weak flow foliation. A trace of relict zircon occurs in the groundmass. The relict characteristics of the rock indicate it represents a vitric-crystal tuff, possibly ignimbritic.

b) Alteration and structure: The original pyroclastic rock was hydrothermally altered, then deformed and later subject to weathering. Replacement of all components except relict quartz and zircon occurred, with an alteration assemblage of fine grained sericite, quartz and minor chlorite, plus trace leucoxene, being formed. Much of the groundmass is composed of fine grained quartz, grading to abundant sericite, but the pseudomorphic aggregates were originally dominated by sericite and chlorite. A weak anastomosing foliation is defined by preferred orientation of the layer silicates. It appears as though a thermal metamorphic overprint occurred, causing formation of minor fine grained biotite, mostly at the pseudomorphic aggregates sites. Rather strong weathering effects were later imposed, causing partial degradation of chlorite and biotite to orange-brown nontronitic clay. There was also patchy impregnation by goethite, especially along foliation planes and at pseudomorphic aggregates sites.

c) Mineralisation: No sulphides or primary oxide minerals were observed.

Mineral Mode (by volume): quartz 55%, sericite 30%, chlorite/biotite/nontronite 14%, goethite 1% and traces of zircon and leucoxene.

Interpretation and comment: It is interpreted that the sample represents a weathered, altered and deformed felsic vitric-crystal tuff. The rock retains scattered relict phenocrystal grains of quartz, but other phenocrystal grains of feldspar and ferromagnesian material, plus lithic/vitric are completely altered. The original groundmass was fine grained and possibly dominated by vitriclastic material, suggesting that the rock could have been ignimbritic. Hydrothermal alteration caused replacement by fine grained quartz and sericite, with minor chlorite. A weak anastomosing foliation was imposed. A subsequent thermal metamorphic overprint may have occurred, forming a little fine grained biotite, mainly at pseudomorphic aggregates sites. Weathering led to significant degradation of chlorite and biotite to nontronite and the formation of goethite impregnations.

152852_TS

Summary: Vitric-crystal felsic tuff, with hydrothermal altered and later thermal metamorphic effects, overprinted by pervasive weak weathering. The rock retains scattered relict phenocrystal grains of quartz, with pseudomorphs after possible vitric/lithic fragments and feldspar and ferromagnesian phenocrysts. The groundmass is fine grained, recrystallised by has vague preservation of fine vitriclastic and pumiceous texture. There is no indication that the rock represents an epiclastic sandstone. Hydrothermal alteration caused replacement by finely granular quartz, subordinate sericite, minor chlorite and trace leucoxene. Later metamorphism led to development of minor fine grained biotite, with subsequently imposed weathering causing partial degradation of chlorite and biotite to nontronite and goethite.

Handspecimen: The sample is composed of a pale grey-green, massive to weakly foliated, strongly altered felsic tuff. It contains apparent small elongate lithic fragments up to a few millimetres across and a few relict phenocrystal quartz grains up to 3 mm across in a fine grained altered groundmass. It is likely that the rock has undergone strong hydrothermal alteration to fine grained sericite, quartz and minor chlorite, with subsequently imposed mild weathering effects. The sample is very weakly magnetic, with susceptibility up to 24 x 10^{-5} SI units.

Petrographic description

a) Primary rock characteristics: In the section, relict texture is moderately preserved. There are scattered relict phenocrystal grains of quartz up to 3 mm across. Also present are scattered pseudomorphic aggregates up to a few millimetres across that could represent former mineral grains (e.g. feldspar, ferromagnesian material) and lithic/vitric fragments, as well as a few small altered microphenocrysts of FeTi oxide. The phenocrystal phases are dispersed in a fine grained altered groundmass with vaguely preserved vitriclastic and possible pumiceous textures. There is also a trace of relict zircon in the groundmass. From the relict characteristics, the rock is interpreted as a vitric-crystal felsic tuff. There is no convincing textural evidence that the rock was originally an epiclastic sandstone.

b) Alteration and structure: Strong pervasive hydrothermal alteration was imposed, with a possible later thermal metamorphic event. Quartz phenocrysts show local development of quartz overgrowths and the groundmass was completely replaced by finely granular quartz, plus subordinate sericite. Other phenocrystal phases and lithic/vitric fragments were altered to sericite and chlorite, with trace leucoxene at former ferromagnesian sites. Igneous FeTi oxide was completely altered to leucoxene. A weak foliation is locally apparent in the altered groundmass. Later thermal metamorphism caused formation of minor amounts of fine grained khaki coloured biotite, mostly at the pseudomorphic aggregates sites, e.g. from replacement of chlorite and sericite. The rock was subject to pervasive mild weathering effects, with partial degradation of biotite/chlorite to nontronitic clay and a little goethite staining.

c) Mineralisation: No sulphides or primary oxide minerals were observed.

Mineral Mode (by volume): quartz 60%, sericite 25%, chlorite/biotite/nontronite 14% and traces of goethite, zircon and leucoxene.

Interpretation and comment: It is interpreted that the sample is a slightly weathered, felsic vitric-crystal tuff, that had experienced hydrothermal alteration and later thermal metamorphic effects. There are scattered relict phenocrystal grains of quartz, with pseudomorphs after possible vitric/lithic fragments and feldspar and ferromagnesian phenocrysts. The groundmass is fine grained, recrystallised by has vague preservation of fine vitriclastic and pumiceous texture. There is no indication that the rock represents an epiclastic sandstone. Hydrothermal alteration caused replacement by finely granular quartz, subordinate sericite, minor chlorite and trace leucoxene. Later metamorphism produced

minor fine grained biotite, with subsequently imposed weathering causing partial degradation of chlorite and biotite to nontronite and goethite.

152853 TS

Summary: Metamorphosed, altered felsic vitric-crystal-lithic tuff. The rock retains a few relict phenocrystal grains of quartz and diffuse pseudomorphs after former feldspar and ferrmagnesian phenocrysts. There are also a couple of possible porphyritic lithic fragments. All occur in a fine grained vitriclastic to pumiceous groundmass. Initial hydrothermal alteration probably caused replacement by an assemblage of quartz, sericite and chlorite. Subsequently, thermal metamorphism produced considerable fine grained biotite, concentrated at former ferromagnesian sites and to a lesser extent in the groundmass. Feldspar phenocrysts were mostly replaced by granular, fine grained quartz. The groundmass is dominated by granular quartz, with subordinate sericite and biotite. Most igneous FeTi oxide and the small amounts of fine grained granular metamorphic magnetite were later replaced by hematite.

Handspecimen: The sample is composed of a massive, medium grey, felsic crystal-lithic tuff. It has a few altered feldspar and relict quartz phenocrysts up to 3 mm across, plus darker pseudomorphic aggregates up to several millimetres across after lithic fragments and after possible ferromagnesian material. There is an apparent fine grained tuffaceous groundmass. The rock could have been altered to fine grained sericite and quartz, but the dark colour in places is probably due to development of fine grained metamorphic biotite. The sample is moderately magnetic, with susceptibility up to 180 x 10^{-5} SI units.

Petrographic description

a) Primary rock characteristics: In the section, relict texture is moderately preserved. There are scattered relict quartz phenocrysts up to 3 mm across, along with "ghosted" pseudomorphs that are probably after former blocky feldspar phenocrysts up to 1.5 mm across and after discrete ferromagnesian phenocrysts up to several millimetres across (some of these could have been biotite). Some of the ferromagnesian sites are associated with FeTi oxide grains up to 1.5 mm across (that are mostly altered) and a trace of zircon. The rock might have also contained a couple of porphyritic lithic fragments up to a few millimetres across. All these components occurred in a fine grained vitriclastic groundmass, that grades in places into evidently coarser, pumiceous material. The groundmass also contains a few FeTi oxide grains (mostly altered) and a trace of zircon. The relict features suggest that the sample is a felsic vitric-crystal-lithic tuff. There is no convincing textural evidence that the rock was originally an epiclastic sandstone.

b) Alteration and structure: The original pyroclastic rock was strongly hydrothermally altered, with subsequent thermal metamorphic effects imposed. The initial alteration assemblage was probably dominated by quartz, sericite and chlorite, but the later metamorphic effects have destroyed chlorite (and some of the sericite) and formed rather abundant metamorphic biotite. Consequently, former feldspar phenocrysts are now represented by fine grained granular quartz pseudomorphs, with minor associated biotite, and former ferromagnesian phenocrysts by fine grained biotite aggregates, associated with a little finely granular magnetite. The groundmass has recrystallised to dominant fine grained quartz, with subordinate sericite and minor biotite, and with sericite preferred orientation locally defining a weak foliation. Subsequently, igneous FeTi oxide and much of the metamorphic biotite associated with biotite aggregates, was replaced by hematite. The considerable amount of metamorphic biotite attests to metamorphism having attained biotite grade. Slight weathering effects are manifest by slight goethite staining along local fractures.

c) Mineralisation: Sparse igneous FeTi oxide grains and the small amounts of fine grained metamorphic magnetite have both been largely replaced by hematite.

Mineral Mode (by volume): quartz 60%, biotite 20%, sericite 19%, hematite 1% and traces of goethite, FeTi oxide (includes magnetite) and zircon.

Interpretation and comment: It is interpreted that the sample represents an altered felsic vitric-crystal-lithic tuff that has experienced subsequent biotite grade metamorphism. It retains relict phenocrystal grains of quartz and diffuse pseudomorphs after former feldspar and ferrmagnesian phenocrysts, along with a few possible porphyritic lithic fragments. All occur in a fine grained vitriclastic to pumiceous groundmass. Initial hydrothermal alteration altered much of the rock to quartz, sericite and chlorite. Subsequently, thermal metamorphism produced fine grained biotite, concentrated at former ferromagnesian sites and to a lesser extent in the groundmass. Feldspar phenocrysts were mostly replaced by granular, fine grained quartz. The groundmass is dominated by granular quartz, with subordinate sericite and biotite. Most igneous FeTi oxide and the small amounts of fine grained granular metamorphic magnetite were later replaced by hematite.

152854 TS

Summary: Felsic vitric-crystal tuff with strong phyllic (quartz-sericite) alteration and subsequent deformation effects. The original rock contained scattered quartz phenocrysts and could have contained a minor amount of feldspar and ferromagnesian phenocrysts, in a fine grained vitriclastic groundmass. Apart from quartz phenocrysts, the remainder of the rock was completely altered and replaced by fine grained quartz, with a network of weakly to moderately foliated sericite-rich foliae intervening. Traces of leucoxene and pyrite were formed as part of the alteration, with pyrite being later replaced by goethite due to supergene oxidation.

Handspecimen: The sample is composed of a pale grey to creamy coloured, strongly altered porphyriic felsic volcanic rock. It contains scattered relict quartz phenocrysts up to 4 mm across in a fine grained quartz-sericite altered groundmass, with a weakly foliated network array of sericite-rich foliae. A little disseminated pyrite could have also formed by alteration, but was subsequently affected by weathering and development of orange-brown goethite impregnation. The sample is essentially non-magnetic, with susceptibility of $<10 \times 10^{-5}$ SI units.

Petrographic description

a) Primary rock characteristics: In the section, it is evident that the original rock was strongly hydrothermally altered and subsequently deformed and consequently relict texture is at best only moderately preserved. There are scattered relict quartz phenocrysts up to 3 mm across and a few small pseudomorphic aggregates after former FeTi oxide grains. The rock may have contained a few feldspar and ferromagnesian phenocrysts, but evidence of these is meagre, with only a couple of "ghosted" aggregates representing possible sites. The groundmass of the rock was originally fine grained and possibly vitriclastic in character, based on vaguely preserved relict texture. There is no strong indication that the rock was originally an epiclastic and therefore it is interpreted as representing a former vitric-crystal felsic tuff.

b) Alteration and structure: The original pyroclastic rock was affected by strong hydrothermal alteration of phyllic type, with later imposed deformation. All groundmass and phenocryst phases (apart from quartz) were replaced, commonly by fine grained, inequigranular quartz, and by an irregular network of anastomosing foliae rich in sericite. Around a few of the relict quartz phenocrysts, there are local quartz overgrowths. A little leucoxene, pyrite and trace apatite formed by alteration, commonly in the sericite-rich zones, but leucoxene also pseudomorphed small igneous FeTi oxide grains. Deformation effects are expressed by local strain and recrystallisation of quartz phenocrysts and by the anastomosing foliation developed in the sericite-rich foliae. A couple of the latter sericite-rich zones up to a few millimetres wide have moderate foliation and may have acted as local shear zones. Patchy weathering effects imposed on the rock have led to replacement of disseminated pyrite by goethite and the formation of goethite impregnations in some of the sericite-rich foliae.

c) Mineralisation: A few grains of pyrite up to 0.6 mm across formed as part of the alteration assemblage, but were later replaced by goethite as a result of supergene oxidation.

Mineral Mode (by volume): quartz 75%, sericite 22%, goethite 3% and traces of leucoxene and apatite.

Interpretation and comment: It is interpreted that the sample is a strongly phyllic altered felsic vitric-crystal tuff. It contains scattered relict quartz phenocrysts and could have contained a minor amount of feldspar and ferromagnesian phenocrysts, in a fine grained vitriclastic groundmass. Apart from quartz phenocrysts, the remainder of the rock was completely altered and replaced by fine grained quartz, with a network of weakly to moderately foliated sericite-rich foliae intervening. Traces of leucoxene and pyrite were

formed as part of the alteration, with pyrite being later replaced by goethite due to supergene oxidation.

152855 TS

Summary: Felsic vitric-crystal-lithic tuff showing scattered relict phenocrystal grains of quartz in a fine groundmass that was dominated by fine pumiceous material and which contained probable ferromagnesian phenocrysts and lithic/vitric fragments, along with a few relict grains of apatite and zircon and small altered grains of FeTi oxide. The rock underwent strong phyllic alteration, with replacement by quartz and sericite, with subsequent development of locally weak to moderate foliation. A thermal metamorphic effect could have been imposed with development of minor fine grained biotite and magnetite. Later, oxidative retrograde alteration caused most magnetite and igneous FeTi oxide to be replaced by hematite.

Handspecimen: The sample is composed of a grey, weakly foliated, felsic volcaniclastic rock. It contains scattered relict phenocrystal grains of quartz up to 3 mm across and altered lithic grains up to a few millimetres across in a fine grained altered groundmass. There are scattered darker coloured (dark grey with mauve hue) masses throughout that appear to represent hematite-altered lithic grains. The rock has probably experienced quartz-sericite alteration along with the development of hematite. The sample is weakly magnetic, with susceptibility up to 60 x 10^{-5} SI units.

Petrographic description

a) Primary rock characteristics: In the section, relict texture is moderately preserved. There are scattered relict quartz grains up to 3 mm across, along with pseudomorphs after possible lithic/vitric fragments and ferromagnesian phenocrysts up to a few millimetres across. Relict shapes suggest that at least some of the ferromagnesian phenocrysts were biotite. There may have been a few feldspar phenocrysts, but if so, their presence is only marked by very diffuse pseudomorphic aggregates. The sample retains a few partly altered microphenocrysts of FeTi oxide up to 0.6 mm across and a couple of blocky prismatic grains of relict apatite up to 0.8 mm across and rare zircon. Relict textures suggest that the groundmass was originally dominated by pumiceous material. Consequently, the original rock is interpreted as a felsic vitric-crystal-lithic tuff, possibly ignimbritic. There is no diagnostic textural evidence to infer that the rock represents an epiclastic sandstone.

b) Alteration and structure: The original pyroclastic rock experienced strong hydrothermal alteration of phyllic type. The dominant groundmass (and any former feldspar phenocrysts) was replaced by dominant finely granular quartz and sericite; the latter is locally abundant, forming weakly to moderately foliated masses up to a few millimetres wide. Former ferromagnesian material and lithic/vitric grains might have originally been altered to quartz, sericite, chlorite and trace leucoxene. However, it appears as though the rock was affected by thermal metamorphism, leading to destruction of any chlorite and formation of minor finely granular magnetite and biotite, mainly at the former ferromagnesian and lithic/vitric fragment sites and in a few foliation-parallel aggregates. Subsequently, most magnetite and igneous FeTi oxide grains were retrogressively replaced by hematite. Some of the metamorphic biotite was also replaced by brownish nontronitic clay, perhaps due to incipient supergene processes.

c) Mineralisation: The rock is interpreted to have developed minor finely granular magnetite, associated with biotite, as a result of metamorphism. Magnetite, along with original igneous FeTi oxide, was largely replaced by retrograde hematite.

Mineral Mode (by volume): quartz 65%, sericite 28%, hematite 5%, nontronite 1% and traces of apatite, zircon, biotite, leucoxene and FeTi oxide/magnetite.

Interpretation and comment: It is interpreted that the sample represents an altered felsic vitric-crystal-lithic tuff. It retains scattered relict phenocrystal grains of quartz in a fine groundmass that was dominated by fine pumiceous material and which contained probable ferromagnesian phenocrysts and lithic/vitric fragments, along with a few relict grains of

apatite and zircon and small altered grains of FeTi oxide. There was strong phyllic alteration, with replacement by quartz and sericite, with subsequent development of locally weak to moderate foliation. A thermal metamorphic effect was imposed with development of minor fine grained biotite and magnetite. Later, oxidative retrograde alteration caused most magnetite and igneous FeTi oxide to be replaced by hematite.

152856 TS

Summary: Porphyritic dacite, with evidence of a metamorphic and/or hydrothermal overprint. The rock retains a few quartz phenocrysts and also contained scattered plagioclase and ferromagnesian phenocrysts, along with a little FeTi oxide and apatite in a fine to medium grained, largely feldspathic groundmass. There was significant replacement of the primary igneous minerals, with plagioclase being mostly altered to albite and K-feldspar and ferromagnesians to actinolite, epidote and fine grained (secondary) biotite, plus a little magnetite. The alteration mineral assemblage is consistent with either having formed by biotite grade thermal metamorphism, or by pervasive hydrothermal alteration of transitional potassic-propylitic type.

Handspecimen: The sample is composed of a massive, dark grey, porphyritic felsic to intermediate, fine grained igneous rock. It appears to contain scattered phenocrysts of quartz, feldspar and ferromagnesian material in a fine grained groundmass and with the dark colour probably due to development of fine grained biotite and/or amphibole. There must be a little magnetite present as the sample is moderately magnetic, with susceptibility up to 950 x 10^{-5} SI units.

Petrographic description

a) Primary rock characteristics: In the section, relict characteristics are moderately well preserved. There are rather sparsely scattered relict quartz phenocrysts up to 2.5 mm across. Scattered pseudomorphs occur after former plagioclase phenocrysts up to 1.5 mm across and there are scattered aggregates that have replaced former ferromagnesian grains that were up to 2.5 mm across. Relict shapes suggest that some of the latter could have included hornblende and/or pyroxene, as well as a little biotite. The sample also retains a few grains of relict FeTi oxide (e.g. titanomagnetite) up to 0.4 mm across, a couple of blocky apatite grains up to 0.6 mm across and a trace of zircon. The groundmass appears to have been dominated by fine to medium grained inequigranular feldspar (probably mostly plagioclase), with minor ferromagnesian material, quartz and FeTi oxide. The groundmass is relatively homogeneous and although it has a rather fractured and granulated appearance, it does not have textures consistent with it representing an epiclastic (e.g. volcaniclastic sandstone). Consequently, the rock is interpreted as an altered porphyritic dacite, possibly representing a volcanic or shallow intrusive.

b) Alteration and structure: It is interpreted that the original igneous rock was hydrothermally altered and/or metamorphosed. Plagioclase was abundant as small phenocrysts and in the groundmass, but was completely replaced by varying amounts of albite and K-feldspar, with minor fine grained biotite and a little epidote. Ferromagnesian grains were replaced mostly by fine to medium grained aggregates of actinolite and epidote, with local khaki biotite, magnetite and traces of titanite and chlorite. In the groundmass, there was partial recrystallisation and replacement, especially by K-feldspar and albite, plus interstitial biotite and small amounts of epidote, actinolite and magnetite. The alteration assemblage is consistent with development under biotite grade metamorphic conditions, but it could alternatively represent a pervasive hydrothermal alteration assemblage, transitional between potassic and propylitic types.

c) Mineralisation: There is a little relict igneous FeTi oxide (titanomagnetite) in grains up to 0.4 mm across. A little magnetite formed as part of the alteration assemblage, mainly at former ferromagnesian sites.

Mineral Mode (by volume): plagioclase (albite) 40%, quartz and K-feldspar each 20%, biotite 8%, actinolite 6%, epidote 3%, FeTi oxide (includes magnetite) 2% and traces of apatite, zircon, titanite and chlorite.

Interpretation and comment: It is interpreted that the sample is a porphyritic dacite, perhaps representing a volcanic or shallow intrusive rock. It retains a few quartz phenocrysts and also

had scattered plagioclase and ferromagnesian phenocrysts, along with a little FeTi oxide and apatite in a fine to medium grained, largely feldspathic groundmass. There was significant replacement of the primary igneous minerals, with plagioclase being mostly altered to albite and K-feldspar and ferromagnesians to actinolite, epidote and fine grained (secondary) biotite, plus a little magnetite. The alteration mineral assemblage is consistent with either having formed by biotite grade thermal metamorphism, or by pervasive hydrothermal alteration of transitional potassic-propylitic type.

152857 TS

Summary: Altered porphyritic dacite, containing a few relict quartz phenocrysts and pseudomorphs after former ferromagnesian and plagioclase phenocrysts in a fine grained, dominantly feldspathic groundmass. Relict shapes of the ferromagnesian pseudomorphs suggest that biotite as well as hornblende or pyroxene were originally present. The rock underwent strong alteration, with replacement of all original feldspar by albite, K-feldspar and a little quartz, epidote and actinolite. Ferromagnesian phases were almost completely replaced by actinolite, with minor epidote and chlorite, and traces of titanite, magnetite and pyrite. Traces of pyrite and chalcopyrite occur in the altered groundmass. The alteration is consistent with either having formed by low grade thermal metamorphism, or by pervasive hydrothermal alteration of transitional potassic-propylitic type.

Handspecimen: The sample is composed of a massive, dark grey, altered porphyritic felsic to intermediate, fine grained igneous rock. It contains a few relict quartz phenocrysts and altered phenocrysts of feldspar and ferromagnesian material, all up to a few millimetres across, in a dark feldspathic groundmass. Altered feldspar phenocrysts are locally pinkish-grey (?K-feldspar alteration) and the rock contains a few apparently replacive aggregates of dark grey-green amphibole up to several millimetres across. The sample is moderately magnetic, with susceptibility up to 430 x 10^{-5} SI units.

Petrographic description

a) Primary rock characteristics: In the section, relict porphyritic texture is moderately preserved. The sample retains a few relict quartz phenocrysts up to 2.5 mm across and pseudomorphs after former phenocrysts of plagioclase (up to 4 mm) and ferromagnesian material (up to 3 mm). There is also a little disseminated FeTi oxide (e.g. titanomagnetite) in grains up to 0.4 mm across, and traces of apatite and zircon. Relict shapes suggest that ferromagnesian phases included biotite (a little relict biotite remains) and hornblende and/or pyroxene. The original groundmass was fine grained, locally with slightly fluidal texture and was feldspathic in composition, with a little quartz and ferromagnesian material. The groundmass appears to be relatively coherent and there is no convincing evidence that the rock represents a volcaniclastic (e.g. epiclastic sandstone). From the relict characteristics, the rock is interpreted as a porphyritic dacite.

b) Alteration and structure: The original igneous rock has been strongly altered. Original phenocrystal and groundmass feldspar was largely replaced by albite, but in places (e.g. at phenocryst sites), there is evidence of replacement by K-feldspar and local quartz, plus a little epidote and actinolite. Most ferromagnesian grains were replaced by aggregates of fine to medium grained actinolite ± epidote (with slight gradation of epidote into brown allanite), along with a little chlorite (at biotite sites) and traces of titanite, magnetite and pyrite. Igneous FeTi oxide is slightly altered to titanite. In the groundmass, there is local development of replacement aggregates up to several millimetres across of fine to medium grained actinolite ± K-feldspar ± quartz. There are also a few grains of pyrite and a tiny trace of chalcopyrite in the altered groundmass. The alteration assemblage is consistent with development under low grade thermal metamorphic conditions, but it could alternatively represent a pervasive hydrothermal alteration assemblage, transitional between potassic and propylitic types.

c) Mineralisation: There is a little relict igneous FeTi oxide (titanomagnetite) in grains up to 0.4 mm across. Alteration has led to traces of magnetite, pyrite and a few tiny grains of chalcopyrite being formed. Pyrite grains are up to 0.4 mm across.

Mineral Mode (by volume): plagioclase (albite) 50%, K-feldspar 20%, quartz 15%, actinolite 10%, epidote (-allanite) 2%, FeTi oxide/magnetite and chlorite each 1% and traces of biotite, apatite, zircon, pyrite, chalcopyrite and titanite.

Interpretation and comment: It is interpreted that the sample represents a porphyritic dacite that has experienced strong pervasive alteration. It retains a few relict quartz phenocrysts and

pseudomorphs after ferromagnesian and plagioclase phenocrysts in a fine grained, feldspathic groundmass. Strong alteration caused replacement of feldspar by albite, K-feldspar and a little quartz, epidote and actinolite. Ferromagnesian phases were almost completely replaced by actinolite, with minor epidote and chlorite, and traces of titanite, magnetite and pyrite. Traces of pyrite and chalcopyrite occur in the altered groundmass. The alteration is consistent with either having formed by low grade thermal metamorphism, or by pervasive hydrothermal alteration of transitional potassic-propylitic type.

152858 TS

Summary: Altered porphyritic dacite, containing a few relict quartz phenocrysts and pseudomorphs after former ferromagnesian and plagioclase phenocrysts in a fine grained, dominantly feldspathic groundmass. The rock was replaced by a generally fine grained assemblage of albite, K-feldspar, quartz, actinolite and epidote, with a few irregular to veinlike aggregates of clinopyroxene, actinolite and minor epidote, magnetite and K-feldspar. There is also a trace of disseminated pyrite and rare chalcopyrite. The alteration is consistent with either having formed by thermal metamorphism (possibly to hornblende hornfels facies), or by pervasive hydrothermal alteration of "mafic potassic" type.

Handspecimen: The sample is composed of a massive, dark grey to grey-green altered and probably metamorphosed porphyritic intermediate to felsic fine grained igneous rock. It contains irregular to veinlike masses of grey-green aggregates up to a few centimetres across, maybe containing calc-silicate minerals (e.g. amphibole, clinopyroxene), enclosed by dark grey altered feldspathic rock in which there are a few relict quartz phenocrysts. There must be a little magnetite as the sample is moderately magnetic, with susceptibility up to 710 x 10^{-5} SI units.

Petrographic description

a) Primary rock characteristics: In the section, relict porphyritic texture is moderately preserved. There are a few relict quartz phenocrysts up to 4 mm across and pseudomorphs after former ferromagnesian phenocrysts (up to 2.5 mm across) and uncommon plagioclase phenocrysts (up to 1.5 mm across). The rock also retains a few relict grains of FeTi oxide (e.g. titanomagnetite) up to 0.6 mm across and a trace of apatite and zircon. The phenocrystal phases occurred in a fine grained feldspathic groundmass, containing minor quartz and altered ferromagnesian grains. Locally, a fluidal texture is vaguely preserved in the groundmass. From the relict characteristics, the rock is interpreted as a porphyritic dacite.

b) Alteration and structure: The original igneous rock was strongly altered, although there is preservation of relict quartz phenocrysts, FeTi oxide and trace apatite and zircon. Phenocrystal and groundmass feldspar was replaced by turbid albite and K-feldspar, with a little quartz, actinolite and epidote. Original ferromagnesian grains were replaced by fine to medium grained aggregates dominated by actinolite, but in places associated with epidote, pale green clinopyroxene, chlorite, magnetite and traces of titanite, carbonate, pyrite and chalcopyrite. There are also a few diffuse replacive aggregates up to several millimetres across and associated anastomosing to sub-planar veins up to 0.4 mm wide that contain fine to medium grained clinopyroxene, with associated actinolite, epidote, magnetite and K-feldspar. The calc-silicate-dominated alteration aggregates could imply development under medium grade metamorphic conditions (e.g. hornblende hornfels facies), or alternatively, they could result from a hydrothermal process creating a "mafic potassic" alteration assemblage, with some affinities to skarn assemblages.

c) Mineralisation: There is a little relict igneous FeTi oxide (titanomagnetite) in grains up to 0.4 mm across. Alteration has led development of a little magnetite and traces of pyrite (grains up to 0.4 mm) and a few tiny grains of chalcopyrite.

Mineral Mode (by volume): plagioclase (albite) 40%, K-feldspar 25%, quartz 15%, actinolite 10%, clinopyroxene 4%, epidote 3%, FeTi oxide/magnetite and chlorite each 1% and traces of apatite, zircon, pyrite, chalcopyrite, carbonate and titanite.

Interpretation and comment: It is interpreted that the sample is an altered porphyritic dacite, containing a few relict quartz phenocrysts and pseudomorphs after former ferromagnesian and plagioclase phenocrysts in a fine grained, dominantly feldspathic groundmass. It was replaced by albite, K-feldspar, quartz, actinolite and epidote, with a few irregular to veinlike aggregates of clinopyroxene, actinolite and minor epidote, magnetite and K-feldspar. There is also a trace of disseminated pyrite and rare chalcopyrite. The alteration assemblage could

have formed by thermal metamorphism (possibly to hornblende hornfels facies), or by pervasive hydrothermal alteration of “mafic potassic” type.

152859 TS

Summary: Altered fractured porphyritic dacite, possibly representing a coarse volcaniclastic rock. There are a few relict quartz phenocrysts and rather abundant albitised plagioclase phenocrysts, along with pseudomorphic aggregates that represent sites of former ferromagnesian phenocrysts. The groundmass of the rock was fine grained and feldspathic and there are also a few relict grains of FeTi oxide (titanomagnetite) and apatite. The rock was replaced by abundant albite, K-feldspar and quartz in the fractured, altered groundmass, and with abundant fine grained biotite, developed at former ferromagnesian sits and in fractures in the groundmass. A little chlorite, actinolite and titanite are associated with biotite. The alteration mineral assemblage could reflect metamorphism of the original rock to biotite grade, or alternatively, it represents the influence of pervasive potassic-propylitic alteration.

Handspecimen: The sample is composed of a massive, dark grey, altered fine grained porphyritic intermediate to felsic igneous rock. It contains scattered altered feldspar and ferromagnesian phenocrysts, plus a few relict quartz phenocrysts, up to a few millimetres across in a fine grained feldspathic groundmass. In places, there is pervasive pink alteration of feldspars and groundmass (K-feldspar alteration). Elsewhere, the dark colour could be due to development of fine grained biotite. There must be a little magnetite as the sample is moderately magnetic, with susceptibility up to 840 x 10^{-5} SI units. Staining of the section offcut with sodium cobaltinitrite showed moderate K-feldspar in the groundmass.

Petrographic description

a) Primary rock characteristics: In the section, relict texture is moderately well preserved. It is interpreted that there is a relict crowded porphyritic texture, with abundant altered blocky plagioclase phenocrysts up to 2 mm across, plus less common pseudomorphs after former ferromagnesian phenocrysts up to 2 mm across (relict shapes suggest hornblende/pyroxene, as well as biotite). The rock retains a few relict quartz phenocrysts up to 2.5 mm across, a little relict FeTi oxide (e.g. titanomagnetite) up to 0.6 mm across, blocky grains of apatite up to 0.6 mm across and a trace of relict zircon. All these phases occur in a finely recrystallised feldspathic groundmass that also contained a little ferromagnesian material and quartz. The groundmass appears to have been fractured such that the rock has a vaguely fragmental texture. The rock is a porphyritic dacite in bulk composition, but there is a possibility that it represents a coarse volcaniclastic.

b) Alteration and structure: It is interpreted that the original rock was strongly and pervasively altered. All original phenocrystal and groundmass plagioclase was replaced by albite, with minor biotite. In the groundmass, there was also recrystallisation to fine grained albite, K-feldspar and quartz, with minor biotite. Fractures in relict quartz and apatite are filled by biotite and a little chlorite and all former ferromagnesian material was replaced by fine grained aggregates of green to khaki biotite, with a little intergrown chlorite, actinolite, titanite and rare pyrite. A weak network fracture system, mainly in the groundmass is occupied by fine grained biotite. The rock was cut by a couple of later thin (<0.3 mm) extensional texture sub-planar veins of fine grained K-feldspar and quartz. The observed alteration effects could be due to a biotite grade thermal metamorphic episode. Alternatively, pervasive hydrothermal alteration of potassic (-propylitic) type was responsible.

c) Mineralisation: The rock retains a little relict igneous FeTi oxide (titanomagnetite) in grains up to 0.6 mm across, showing slight alteration to leucoxene. A trace of pyrite has formed as part of the alteration assemblage, mainly associated with altered ferromagnesian sites.

Mineral Mode (by volume): albite 45%, K-feldspar 20%, biotite 16%, quartz 15%, chlorite 2%, FeTi oxide 1% and traces of titanite, leucoxene, actinolite, pyrite, apatite and zircon.

Interpretation and comment: It is interpreted that the sample represents a fractured porphyritic dacite, possibly a coarse volcaniclastic, and with strong pervasive alteration. There are a few relict quartz phenocrysts and abundant albitised plagioclase phenocrysts,

along with pseudomorphic aggregates after former ferromagnesian phenocrysts. The groundmass was fine grained and feldspathic. The rock was replaced by abundant albite, subordinate greenish biotite, K-feldspar and quartz. Biotite, is mainly developed at former ferromagnesian sits and in fractures in the groundmass. A little chlorite, actinolite and titanite are associated with biotite. The alteration mineral assemblage could reflect metamorphism of the original rock to biotite grade, or alternatively, it represents the influence of pervasive potassic-propylitic alteration.

152860 TS

Summary: Strongly altered porphyritic dacite, possibly of pyroclastic origin, and strongly recrystallised. The original rock contained a few phenocrysts of quartz and there are pseudomorphs after former ferromagnesian phenocrysts and a few small feldspar phenocrysts. The groundmass was of quartzofeldspathic composition, but recrystallisation has obscured definitive relict features; however, it is speculated that it could have included pumiceous material, including elongate fragments. Alteration has led to replacement of the groundmass and feldspar phenocrysts by fine, inequigranular K-feldspar, albite and quartz, with ferromagnesian components replaced mostly by actinolite, epidote and minor biotite. Weakly foliated biotite is characteristically developed in the recrystallised groundmass. The alteration assemblage could be due to biotite grade metamorphism or alternatively to pervasive "mafic potassic" hydrothermal alteration.

Handspecimen: The sample is composed of a weakly foliated, dark grey, altered porphyritic fine grained intermediate to felsic igneous rock. It contains scattered altered feldspar and ferromagnesian phenocrysts and a few relict quartz phenocrysts up to 3 mm across in a fine grained altered feldspathic groundmass. There are weakly foliated aggregates of grey-green material (?amphibole), with the dark colour of the groundmass possibly due to the presence of biotite. The sample is moderately magnetic, with susceptibility up to 230 x 10^{-5} SI units.

Petrographic description

a) Primary rock characteristics: In the section, relict texture is moderately preserved. There are a few relict quartz phenocrysts up to 3 mm across and pseudomorphs after scattered ferromagnesian phenocrysts up to 2 mm across. A few "ghosted" pseudomorphs after former small feldspar phenocrysts up to 1 mm across occur, but are ill-defined. The groundmass is strongly recrystallised, but it was originally fine grained and of quartzofeldspathic composition. Vaguely preserved relict textures in the groundmass suggest that the rock could have been pyroclastic, with a few diffuse elongate fragments and possible "frothy" pumiceous material. In the groundmass, there are also a few partly altered FeTi oxide grains (e.g. titanomagnetite) up to 0.5 mm across and traces of apatite and zircon. The overall composition of the rock is dacitic.

b) Alteration and structure: The original rock was strongly altered and recrystallised, with development of a weak to locally moderate foliation. The original quartzofeldspathic groundmass and feldspar phenocrysts were recrystallised to rather fine grained, inequigranular aggregates of K-feldspar, albite and subordinate quartz, with minor biotite and a little epidote and actinolite. Original ferromagnesian phases were replaced by fine to medium grained aggregates of actinolite and epidote, with minor biotite on their margins and trace titanite. FeTi oxide is partly replaced by titanite, actinolite and trace leucoxene. Foliation in the sample is defined by preferred orientation of aggregates of biotite ± epidote ± actinolite, along with apparently sheared former fragments. The alteration assemblage could have formed by biotite grade metamorphism, or alternatively it reflects recrystallisation of the rock under conditions of pervasive "mafic potassic" hydrothermal alteration.

c) Mineralisation: The rock retains a little relict igneous FeTi oxide (titanomagnetite) in grains up to 0.5 mm across.

Mineral Mode (by volume): K-feldspar 35%, albite 30%, quartz 15%, biotite 7%, actinolite 6%, epidote 5%, FeTi oxide 1% and traces of apatite, zircon, titanite and leucoxene.

Interpretation and comment: It is interpreted that the sample is a porphyritic dacite, possibly a pyroclastic, with strong alteration and recrystallisation. It contained a few phenocrysts of quartz along with pseudomorphs after former ferromagnesian phenocrysts and a few small feldspar phenocrysts. The groundmass was of quartzofeldspathic composition, and although recrystallised, it is speculated that it could have included pumiceous fragmental material. Alteration caused replacement of the groundmass and feldspar phenocrysts by fine,

inequigranular K-feldspar, albite and quartz, with ferromagnesian components replaced mostly by actinolite, epidote and minor biotite. Weakly foliated biotite is characteristically developed in the recrystallised groundmass. The alteration assemblage could be due to biotite grade metamorphism or alternatively to pervasive “mafic potassic” hydrothermal alteration.

152861 TS

Summary: Porphyritic dacite, with strong alteration, perhaps caused by biotite grade metamorphism, or pervasive hydrothermal alteration of "mafic potassic" or transitional propylitic-potassic type. The rock retains a few relict quartz phenocrysts and a few microphenocrysts of FeTi oxide and apatite. Former plagioclase and ferromagnesian phenocrysts are completely altered. The groundmass appears to have been coherent, fine to medium grained, inequigranular and of broadly feldspathic composition. Alteration has led to replacement of much of the rock by albite, K-feldspar and subordinate quartz, biotite, actinolite and minor epidote, with a few replacive patches dominated by actinolite and biotite.

Handspecimen: The sample is composed of a massive, dark greenish-grey, porphyritic fine grained intermediate to felsic igneous rock. It has scattered altered feldspar phenocrysts and a few relict quartz and altered ferromagnesian phenocrysts, with largest phenocrysts up to 4 mm across, set in a fine grained feldspathic groundmass. The colour of the rock could be due to development of amphibole, chlorite and biotite. A little magnetite must occur, as the rock is moderately magnetic, with susceptibility up to 770 x 10^{-5} SI units.

Petrographic description

a) Primary rock characteristics: In the section, relict texture is moderately well preserved. There are a few relict quartz phenocrysts (some embayed) up to 4 mm across, scattered pseudomorphs after former plagioclase phenocrysts up to 2 mm across and a few pseudomorphs after former ferromagnesian phenocrysts up to 1.5 mm across. Relict shapes of the latter suggest that hornblende and/or pyroxene, as well as biotite, could have been present. The rock retains a few relict FeTi oxide grains and apatite, both up to 0.8 mm across. The groundmass appears to be relatively coherent and although somewhat fractured and partly recrystallised, there are no diagnostic textures to indicate that the rock was of fragmental type. The groundmass is fine to medium grained, inequigranular and of feldspathic composition, with minor quartz and ferromagnesian material. The relict characteristics indicate that the sample represents an altered porphyritic dacite.

b) Alteration and structure: The original rock was strongly altered and partly recrystallised. Plagioclase phenocrysts were albitised, but also locally replaced by K-feldspar, quartz, epidote, actinolite and biotite. Ferromagnesian grains were mostly replaced by actinolite and minor epidote, although a few have significant chlorite. At ferromagnesian sites, there is also local biotite and traces of magnetite and titanite. The groundmass was partly recrystallised to inequigranular albite, K-feldspar, minor quartz and interstitial biotite, with a little actinolite in places. Locally, there has been development of replacive aggregates up to several millimetres across that contain abundant actinolite and subordinate biotite. A weak foliation is locally apparent in the groundmass, defined by slight preferred orientation of ferromagnesian aggregates. The alteration assemblage could have formed by biotite grade metamorphism, or alternatively it reflects recrystallisation of the rock under conditions of pervasive "mafic potassic" or transitional potassic-propylitic hydrothermal alteration. In part of the section it is evident that slight weathering has affected the rock, with degradation of biotite to orange-brown nontronite.

c) Mineralisation: A few relict igneous FeTi oxide (titanomagnetite) grains up to 0.8 mm across occur and there is a trace of magnetite at some altered ferromagnesian sites.

Mineral Mode (by volume): albite 40%, K-feldspar 25%, quartz 15%, biotite and actinolite each 7%, epidote 3%, FeTi oxide and chlorite each 1% and traces of apatite, titanite and nontronite.

Interpretation and comment: It is interpreted that the sample represents a porphyritic dacite. It has a few relict quartz phenocrysts and a few microphenocrysts of FeTi oxide and apatite. Former plagioclase and ferromagnesian phenocrysts are completely altered. The groundmass

appears to have been coherent, fine to medium grained, inequigranular and of broadly feldspathic composition. Alteration was caused by biotite grade metamorphism, or pervasive hydrothermal alteration of “mafic potassic” or transitional propylitic-potassic type and has led to replacement of much of the rock by albite, K-feldspar and subordinate quartz, biotite, actinolite and minor epidote, with a few replacive patches dominated by actinolite and biotite.

152862 TS

Summary: Porphyritic dacite, possibly with pumiceous quartzofeldspathic groundmass, and with strong alteration caused by biotite grade metamorphism, or by pervasive hydrothermal alteration of "mafic potassic" type. The rock contains scattered relict quartz phenocrysts, pseudomorphs after former ferromagnesian phenocrysts, as well as after a few plagioclase phenocrysts. The groundmass appears to have relict pumiceous texture, with a few possible fragments and weak flow foliation. Subsequently, the rock underwent penetrative deformation, with development of a tectonic foliation. Alteration led to replacement of the groundmass and feldspar phenocrysts by finely inequigranular albite, quartz, K-feldspar and biotite. The rock also has scattered replacement aggregates of dominant biotite, K-feldspar and actinolite, with a little epidote, titanite, magnetite, pyrite and pyrrhotite, at former ferromagnesian sites and in the groundmass.

Handspecimen: The sample is composed of a massive, altered porphyritic, fine grained intermediate to felsic igneous rock. There are a few glassy quartz phenocrysts up to 4 mm across and altered ferromagnesian phenocrysts in a dark grey altered feldspathic groundmass that is probably dark grey because of the presence of fine grained biotite. There is a little disseminated pyrite in grains up to 1 mm across and a little magnetite, as the rock is moderately magnetic, with susceptibility up to 600 x 10^{-5} SI units.

Petrographic description

a) Primary rock characteristics: In the section, relict texture is moderately well preserved. The rock has a porphyritic and possibly pumiceous texture. There are a few relict quartz phenocrysts up to 4 mm across and scattered pseudomorphs after former ferromagnesian phenocrysts (could have included former hornblende and/or pyroxene, as well as biotite) up to 3.5 mm across, as well as a few "ghosted" phenocrysts of plagioclase up to 2 mm across, FeTi oxide grains up to 0.5 mm across and a trace of apatite and zircon. A fine grained, partly recrystallised quartzofeldspathic groundmass occupies about 75% of the rock and it has possible retention of relict pumiceous texture, local fluidal texture and one or two completely altered lithic/vitric fragments. From the relict features, the sample is interpreted as a porphyritic dacite, with a pumiceous groundmass, i.e. a vitric (pumiceous)-crystal pyroclastic.

b) Alteration and structure: The original rock was strongly altered, partly recrystallised and has weak penetrative deformation features. Original ferromagnesian grains were replaced by aggregates that contain fine to medium grained biotite and K-feldspar, varying to actinolite and K-feldspar, with locally associated epidote, pyrite and trace titanite, magnetite and pyrrhotite. Original plagioclase phenocrysts were replaced by turbid albite and/or K-feldspar and biotite. The groundmass was replaced by fine grained, inequigranualr albite, quartz, minor K-feldspar, biotite and traces of chlorite, actinolite, titanite, pyrite, pyrrhotite and chalcopyrite, Igneous FeTi oxide was locally replaced by titanite. A weak foliation is evident in the groundmass and it is apparent that it was overprinted by the development of biotite (overgrowing the foliation and with random orientation). Similarly, scattered replacive aggregates up to a few millimetres across of biotite, K-feldspar and/or actinolite also have randomly oriented minerals. The alteration mineral assemblage is consistent with the rock having been metamorphosed to biotite grade, or alternatively, affected by pervasive hydrothermal alteration of "mafic potassic" type.

c) Mineralisation: The rock contains a few relict igneous FeTi oxide (titanomagnetite) grains up to 0.5 mm across. Alteration has caused development of a little disseminated pyrite (grains up to 0.8 mm across), pyrrhotite (up to 0.5 mm) and traces of magnetite and chalcopyrite, mostly at altered ferromagnesian sites, but also in the groundmass.

Mineral Mode (by volume): quartz and albite each 30%, K-feldspar 20%, biotite 10%, actinolite 5%, epidote 2%, FeTi oxide/magnetite and pyrite each 1% and traces of chlorite, apatite, titanite, zircon, pyrrhotite and chalcopyrite.

Interpretation and comment: It is interpreted that the sample is a porphyritic dacite, possibly pyroclastic, and with strong alteration caused by biotite grade metamorphism, or by pervasive hydrothermal alteration of "mafic potassic" type. The rock contains scattered relict quartz phenocrysts, pseudomorphs of former ferromagnesian phenocrysts, as well as after a few plagioclase phenocrysts. The groundmass may have relict pumiceous texture, with a few possible fragments and weak flow foliation. Subsequently, the rock underwent penetrative deformation, with development of a tectonic foliation. Alteration led to replacement of the groundmass and feldspar phenocrysts by finely inequigranular albite, quartz, K-feldspar and biotite. The rock also has scattered replacement aggregates of dominant biotite, K-feldspar and actinolite, with a little epidote, titanite, magnetite, pyrite and pyrrhotite, at former ferromagnesian sites and in the groundmass.

152863 TS

Summary: Strongly porphyritic hornblende-quartz andesite (or microdiorite), possibly representing a shallow intrusive. The rock displays strong pervasive alteration. It has abundant altered plagioclase phenocrysts, less common, variably altered ferromagnesian phenocrysts (including relict brown hornblende) and a few quartz phenocrysts. The groundmass component was dominated by plagioclase and had a fine grained, inequigranular texture, with a few entrained microphenocrysts of FeTi oxide (titanomagnetite) and apatite. Alteration of the rock led to albitisation of plagioclase and extensive replacement of ferromagnesian material, and in places the groundmass, plagioclase and quartz phenocrysts, by actinolite and biotite, with minor epidote and magnetite. This assemblage could be due to biotite grade thermal metamorphis, or alternatively represent the product of pervasive "mafic potassic" hydrothermal alteration.

Handspecimen: The sample is composed of a massive, dark grey to greenish-grey, strongly altered, fine to medium grained porphyritic intermediate to felsic igneous rock. It contained altered feldspar and ferromagnesian phenocrysts, along with a few relict quartz phenocrysts, up to a few millimetres across, in an altered feldspathic groundmass. The colour of the rock is probably due to development of biotite and amphibole during alteration. The rock must contain minor magnetite, as it is strongly magnetic, with susceptibility up to 1650 x 10^{-5} SI units.

Petrographic description

a) Primary rock characteristics: In the section, relict strongly porphyritic texture is moderately well preserved. Phenocrystal phases are commonly crowded and the groundmass component occupies about 50%. There are abundant altered plagioclase phenocrysts up to 2.5 mm across, less common, variably altered ferromagnesian phenocrysts up to 2 mm across and a few relict quartz phenocrysts up to 2.5 mm across. Amongst the ferromagnesian phenocrysts, there are scattered relict brown hornblende grains, with other pseudomorphic shapes suggesting that hornblende and/or pyroxene would have been the precursor mineral. There are also a few microphenocrysts of FeTi oxide (titanomagnetite) up to 0.6 mm across, a few grains of apatite and rare zircon associated with the ferromagnesian sites. The groundmass is fine grained and inequigranular, dominated by small plagioclase grains and with a little ferromagnesian material and interstitial quartz and K-feldspar. The mineralogical composition of the primary rock suggests that it is a porphyritic hornblende-quartz andesite (or microdiorite), with the texture implying that it could represent a shallow intrusive.

b) Alteration and structure: The original rock was subject to strong alteration. Original plagioclase phenocrysts and groundmass material were albitised and locally replaced by fine grained actinolite, greenish biotite and epidote. Ferromagnesian phenocrysts are partly to completely replaced by actinolite ± biotite, with a little magnetite and trace titanite. Quartz phenocrysts are also partly replaced by actinolite. In the groundmass, there was partial recrystallised to fine grained albite and minor quartz, K-feldspar, biotite and actinolite. In places, the rock shows replacement by irregular patches up to a few centimetres across of fine to medium grained actinolite, along with fine grained greenish biotite, with a little epidote, albite and magnetite. The alteration mineral assemblage is consistent with the rock having been metamorphosed to biotite grade, or alternatively, affected by pervasive hydrothermal alteration of "mafic potassic" type.

c) Mineralisation: The rock contains a few relict igneous FeTi oxide (titanomagnetite) grains up to 0.6 mm across. Minor fine grained magnetite and a trace of pyrite have formed by alteration, mainly at former ferromagnesian sites and by replacement of the groundmass, associated with biotite and actinolite.

Mineral Mode (by volume): albite 60%, actinolite 12%, biotite 10%, quartz and K-feldspar each 5%, hornblende 4%, FeTi oxide/magnetite 2%, epidote 1% and traces of apatite, zircon, titanite and pyrite.

Interpretation and comment: It is interpreted that the sample represents a crowded porphyritic texture hornblende-quartz andesite (or microdiorite), possibly representing a shallow intrusive. It has abundant altered plagioclase phenocrysts, less common, variably altered ferromagnesian phenocrysts (including relict brown hornblende) and a few quartz phenocrysts. The groundmass component was dominated by plagioclase and had a fine grained, inequigranular texture, with a few entrained microphenocrysts of FeTi oxide (titanomagnetite) and apatite. Strong pervasive alteration caused albitisation of plagioclase and extensive replacement of ferromagnesian material, and in places the groundmass, plagioclase and quartz phenocrysts, by actinolite and biotite, with minor epidote and magnetite. This assemblage could be due to biotite grade thermal metamorphis, or alternatively represent the product of pervasive "mafic potassic" hydrothermal alteration.

152864 TS

Summary: Coarsely quartz-porphyritic felsic volcanic rock, perhaps of rhyodacite composition, with imposed alteration, deformation and metamorphic effects. Apart from quartz phenocrysts, the rock had a few ferromagnesian phenocrysts and one or two feldspar phenocrysts, along with a few apatite microphenocrysts. The groundmass was fine grained, or quartzofeldspathic composition and with possible flow foliation. Early alteration could have caused the groundmass to be replaced by an assemblage of K-feldspar, quartz, albite and sericite, and there was development of a weak foliation and local "pressure shadows" about relict quartz phenocrysts. Metasomatic replacement patches developed prior to, or during biotite grade metamorphism and are now manifest as fine to medium grained aggregates of K-feldspar, with minor epidote, chlorite and quartz. Former ferromagnesian grains are pseudomorphed by fine grained biotite.

Handspecimen: The sample is composed of a fine grained, dark grey-brown, quartz-porphyritic felsic igneous rock. There are prominent pale grey to milky quartz phenocrysts up to 1 cm across in a fine grained, altered feldspathic groundmass that probably contains minor biotite. A weak foliation is apparent in the groundmass. The sample is essentially non-magnetic, with susceptibility of $<10 \times 10^{-5}$ SI units.

Petrographic description

a) Primary rock characteristics: In the section, there are scattered coarse quartz phenocrysts up to 1 cm across. Elsewhere, there are pseudomorphs after former ferromagnesian phenocrysts up to 3.5 mm across (at least some of which were biotite, judging by relict shapes), and also after one or two possible former feldspar phenocrysts. Associated with some of the pseudomorphs after ferromagnesian material are a few relict microphenocrysts of apatite up to 0.8 mm across and a trace of zircon. The phenocrystal phases occurred in a fine grained quartzofeldspathic groundmass that has relict fluidal texture. There is no convincing textural evidence that the groundmass was originally composed of fragmental material. From the relict characteristics, the rock is interpreted as a porphyritic rhyodacite.

b) Alteration and structure: The original igneous rock was hydrothermally altered, deformed and probably later metamorphosed. The fine grained groundmass and possible feldspar phenocrysts were replaced by finely granular K-feldspar, quartz, albite and sericite, with later, overprinting fine grained biotite developing rather abundantly. Former ferromagnesian phenocrysts were replaced by biotite, with a little chlorite, epidote and trace leucoxene and hematite. Scattered throughout are apparent metasomatic replacement aggregates up to several millimetres across that contain abundant fine to medium grained K-feldspar, with minor epidote, chlorite and quartz and a trace of titanite. In places, these aggregates form as "pressure shadows" adjacent to relict quartz phenocrysts. The rock has a weak foliation, defined by preferred orientation of altered ferromagnesian aggregates, but within these, fine grained biotite has a random orientation, suggesting that it grew after deformation occurred. The alteration mineral assemblage could have formed by metamorphism to biotite grade, but it is likely that potassic alteration occurred prior to, or during, metamorphism.

c) Mineralisation: No primary oxide, or sulphide minerals, are recognised.

Mineral Mode (by volume): K-feldspar 45%, quartz 25%, biotite 14%, albite 10%, epidote and chlorite each 2%, sericite 1% and traces of titanite, leucoxene, hematite, apatite and zircon.

Interpretation and comment: It is interpreted that the sample is a quartz-porphyritic felsic volcanic rock, perhaps of rhyodacite composition, with imposed alteration, deformation and metamorphic effects. It has scattered large quartz phenocrysts, with pseudomorphs after ferromagnesian phenocrysts and after one or two feldspar phenocrysts. The groundmass was fine grained, or quartzofeldspathic composition and with possible flow foliation. Early alteration led to replacement of the groundmass by K-feldspar, quartz, albite and sericite, and there was development of a weak foliation and local "pressure shadows" about relict quartz

phenocrysts. Metasomatic replacement patches developed prior to, or during biotite grade metamorphism and are now manifest as fine to medium grained aggregates of K-feldspar, with minor epidote, chlorite and quartz. Former ferromagnesian grains are pseudomorphed by fine grained biotite.

152865 TS

Summary: Hydrothermally altered, deformed and subsequently metamorphosed porphyritic felsic volcanic rock, possibly originally of rhyodacitic composition. The rock retains scattered quartz phenocrysts, but all other phenocryst phases (ferromagnesians including biotite, and possible feldspar) were completely altered. The phenocrysts occurred in a fine grained quartzofeldspathic groundmass. It is interpreted that initial alteration might have produced a fine grained assemblage of quartz and sericite, with lesser amounts of K-feldspar and chlorite. Imposed deformation led to development of a moderate foliation, defined mostly by sericite aggregates. Subsequent metamorphism led to destruction of chlorite and crystallisation of significant fine grained biotite, overprinting the foliation and associated with traces of magnetite (partly altered to hematite) and tourmaline.

Handspecimen: The sample is composed of a moderately foliated, altered porphyritic felsic volcanic rock. It contains scattered relict quartz phenocrysts up to 5 mm across in a rather sheared fine grained groundmass containing pale grey quartz and sericite, with darker elongate masses containing biotite. The sample is weakly magnetic, with susceptibility up to 100×10^{-5} SI units.

Petrographic description

a) Primary rock characteristics: In the section, there are scattered relict quartz phenocrysts up to 5 mm across, but the remainder of the rock is deformed and recrystallised, with relict texture being generally poorly preserved. It is likely that there were scattered ferromagnesian phenocrysts up to a few millimetres across, as well as a few possible feldspar phenocrysts, with the phenocrystal phases occurring in a fine grained quartzofeldspathic groundmass that retains a few relict grains of zircon. There are no diagnostic textures preserved in the groundmass, but it could be speculated that it was originally of vitriclastic type and that there is a possibility that the rock is ignimbritic. The bulk composition suggests that the rock is a porphyritic rhyodacite and showing similarities with sample 152864.

b) Alteration and structure: Hydrothermal alteration, deformation and later metamorphic effects were imposed on the original rock. The groundmass was initially replaced by finely granular quartz, with subordinate sericite, K-feldspar and probable chlorite. Feldspar and ferromagnesian phenocrysts were replaced by varying proportions of quartz, sericite and chlorite. Imposed deformation caused development of a moderate foliation, defined by sericite-rich aggregates up to a few millimetres wide. Uncommon, folded syn-tectonic quartz veining occurred and there was local development of quartz ± sericite "pressure shadows" about quartz phenocrysts. A thermal metamorphic overprint occurred, destroying chlorite and leading to formation of considerable fine grained khaki biotite, concentrated at former ferromagnesian phenocryst sites and in sericite-rich parts of the altered groundmass. Associated with biotite aggregates are traces of fine grained magnetite (partly altered to hematite) and blue tourmaline. The groundmass also recrystallised and former feldspar phenocryst sites were replaced by fine to medium grained aggregates of quartz ± K-feldspar ± biotite. Adjacent to a few of the quartz phenocrysts, there are small aggregates of recrystallised quartz ± magnetite (partly altered to hematite) and tourmaline. It is notable that biotite in overprinting aggregates has random orientation and that it post-dated foliation development. The mineral assemblage implies that metamorphism attained biotite grade.

c) Mineralisation: A trace of magnetite, mostly fine grained, but in grains up to 0.7 mm across, formed as part of the metamorphic assemblage. Magnetite was locally replaced by hematite.

Mineral Mode (by volume): quartz 55%, sericite 25%, biotite 14%, K-feldspar 5% and traces of magnetite, hematite, tourmaline and zircon.

Interpretation and comment: It is interpreted that the sample represents a porphyritic rhyodacite, possibly originally ignimbritic, with imposed hydrothermal alteration,

deformation and later metamorphism. . It retains scattered quartz phenocrysts, but other phenocryst phases (ferromagnesians, possible feldspar) were completely altered. The phenocrysts occurred in a fine grained quartzofeldspathic groundmass. It is interpreted that initial alteration might have produced a fine grained assemblage of quartz and sericite, with lesser amounts of K-feldspar and chlorite. Imposed deformation led to development of a moderate foliation, defined mostly by sericite aggregates. Subsequent metamorphism led to destruction of chlorite and crystallisation of significant fine grained biotite, overprinting the foliation and associated with traces of magnetite (partly altered to hematite) and tourmaline.

CETD1 363.5 m PTS

Summary: Hydrothermally altered, deformed and metamorphosed laminated volcaniclastic sandstone and siltstone. Compositional laminations are diffusely preserved and the sandstone component has a matrix-supported texture, with scattered detrital grains of former volcanic phenocrystal quartz and a few grains of altered FeTi oxide and relict apatite in a recrystallised silty matrix. The siltstone component has scattered small, partly recrystallised detrital quartz grains. Matrix material in the rock was apparently hydrothermally altered, with formation of an assemblage of fine grained quartz, chlorite and sericite, with a small amount of sulphides and leucoxene. A moderate foliation was imposed, defined by preferred orientation of the layer silicates and oblique to the bedding laminations. Subsequently, the rock may have been thermally metamorphosed, with development of a little randomly oriented biotite, porphyroblastic pyrite, a little fine grained magnetite and trace chalcopyrite.

Handspecimen: The drill core is composed of a grey-green, compositionally laminated, fine to medium grained sedimentary rock, with strong alteration imposed. Compositional laminations are on a centimetre scale and at a low angle to the core axis. They are defined by differences in grainsize, by occurrence of scattered quartz grains up to 2 mm across in coarser laminations and by occurrence of disseminated pyrite in some laminations. The rock evidently contains abundant chlorite and probably also significant sericite and quartz, along with a little pyrite and magnetite. A weak foliation is defined by preferred orientation of the layer silicates and is oblique to the compositional laminations and at a moderate angle to the core axis. Due to the presence of magnetite, the sample is moderately magnetic, with susceptibility up to 600 x 10^{-5} SI units.

Petrographic description

a) Primary rock characteristics: In the section, relict compositional layering is discernable, defined by differences in detrital mineral grainsize. One lamination is 2^{+}cm wide and displays a matrix-supported texture, with scattered former volcanic phenocrystal quartz grains up to 2.5 mm across and a few smaller detrital grains of altered FeTi oxide and relict apatite, hosted in a foliated, altered, originally silty matrix. This rock type is interpreted as a volcaniclastic sandstone, derived from a felsic volcanic source. It has a relatively sharp boundary with fine grained, recrystallised altered siltstone, containing scattered small (<0.2 mm) partly recrystallised detrital quartz grains in a fine grained foliated matrix.

b) Alteration and structure: The original bedded siltstone-sandstone was hydrothermally altered, deformed and probably subsequently metamorphosed. Apart from relict quartz and apatite grains, all other phases were altered, with the rock being dominated by fine grained quartz, chlorite and sericite, with the latter phase mostly in the volcaniclastic sandstone matrix. Original detrital FeTi oxide grains were replaced by leucoxene. A moderate foliation occurs, defined by preferred orientation of sericite and chlorite, and it is at a moderate angle to compositional layering. The rock was subsequently metamorphosed, indicated by sparse development of randomly oriented fine grained biotite. In the volcaniclastic sandstone, there is a little fine grained metamorphic magnetite and the rock contains minor porphyroblastic fine to medium grained pyrite, mainly in the siltstone and locally concentrated along bands parallel to compositional layering. Textures suggest that some of the fine grained pyrite has replaced earlier pyrrhotite. The alteration assemblage also contains traces of fine grained chalcopyrite. A couple of thin (<0.2 mm), fine grained recrystallised quartz-rich veins occur approximately parallel to the foliation in the siltstone.

c) Mineralisation: Minor metamorphic, fine to medium grained porphyroblastic pyrite developed, mostly in the altered siltstone, with subhedral grains up to 0.5 mm across and fine grained irregular aggregates up to 1 mm across. Pyrite is locally concentrated in bands parallel to compositional layering. The fine grained pyrite aggregates could have pseudomorphed earlier pyrrhotite. A little fine grained magnetite, and trace chalcopyrite, locally forming composites with pyrite, occur sparsely throughout.

Mineral Mode (by volume): quartz 55%, sericite and chlorite each 20%, pyrite 2%, leucoxene, magnetite and biotite each 1% and traces of apatite and chalcopyrite.

Interpretation and comment: It is interpreted that the sample is a laminated volcaniclastic sandstone and siltstone that has been altered and deformed. Compositional laminations are preserved, with matrix-supported sandstone intercalated with siltstone. The sandstone has scattered detrital grains of former volcanic phenocrystal quartz and a few grains of altered FeTi oxide and relict apatite in a recrystallised silty matrix. The siltstone has scattered small, partly recrystallised detrital quartz grains. Matrix material was hydrothermally altered, with formation of fine grained quartz, chlorite and sericite, with a small amount of sulphides and leucoxene. A moderate foliation was imposed, defined by preferred orientation of the layer silicates and oblique to the bedding laminations. Subsequently, the rock may have been thermally metamorphosed, with development of a little randomly oriented biotite, porphyroblastic pyrite, a little fine grained magnetite and trace chalcopyrite. There is no evidence that the sample contains an alteration boundary.

CETD1 442.6 m TS

Summary: Porphyritic, fine grained felsic igneous rock, possibly representing a volcanic or shallow intrusive and containing scattered quartz phenocrysts in a fine grained quartzofeldspathic groundmass. The rock is strongly to intensely altered. The nature of early alteration is obscure, but part of the rock shows indications of thermal metamorphism, causing replacement of the groundmass by finely granular quartz, K-feldspar and biotite, with patchy sericite and a little epidote and chlorite. This zone borders on to the intense alteration zone where the rock is almost completely replaced by fine to medium grained epidote and chlorite, with subordinate interstitial quartz, minor pumpellyite and a little carbonate, magnetite, titanite and pyrite. The intense alteration appears to be retrograde with respect to the biotite-bearing metamorphic assemblage and implies considerable metasomatic introduction of Ca, Mg and Fe.

Handspecimen: The drill core sample has a relict porphyritic texture, with scattered relict quartz phenocrysts up to 5 mm across in a fine grained altered groundmass. An alteration contact is apparent approximately normal to the core axis. Portion of the rock has pale yellow-green-grey alteration and is evidently epidote-rich with subordinate chlorite. The other part is dark grey, possibly quartzofeldspathic in composition and with fine grained biotite causing the dark colour. The sample must contain a little magnetite, as it is moderately to strongly magnetic, with susceptibility up to 1230 x 10^{-5} SI units.

Petrographic description

a) Primary rock characteristics: In the section, it is evident that the sample has an intense alteration zone bordering on to a less altered zone. Relict quartz phenocrysts up to 4 mm across are present throughout and in the less altered zone there are a few relict FeTi oxide grains up to 0.6 mm across and trace relict apatite and zircon, set in a fine grained recrystallised quartzofeldspathic groundmass. It is possible that a couple of strongly recrystallised fragments up to a few millimetres across are also present. From the relict characteristics, it is speculated that the original rock was a quartz-phyric felsic volcanic or shallow intrusive.

b) Alteration and structure: The less altered portion of the rock has moderate preservation of relict porphyritic texture, but the groundmass is finely recrystallised and replaced by granular quartz and K-feldspar, with minor biotite (locally in aggregates), sericite, a few aggregates of epidote, chlorite and a little magnetite and leucoxene. Towards the boundary of the intensely altered zone, there is an increase in the amounts of fine grained biotite, sericite, chlorite and minor magnetite. The majority of the sample has been completely replaced, except for a few relict quartz phenocrysts, by a fine to medium grained inequigranular assemblage of epidote (grains up to 1.5 mm across), chlorite, subordinate interstitial quartz, scattered aggregates of fine grained pumpellyite up to 1.5 mm across, a little carbonate, few grains of titanite, magnetite (aggregates up to 1 mm across) and uncommon pyrite. The intense alteration zone formed under low grade conditions (sub-greenschist as indicated by the presence of pumpellyite) and it may be a retrograde overprint on an earlier biotite grade thermal metamorphic assemblage. The intense alteration zone could have had strong metasomatic introduction of Ca, Mg and Fe.

c) Mineralisation: A little relict igneous FeTi oxide might occur in the less altered portion of the sample, but it could be significantly replaced by magnetite. Elsewhere, magnetite forms sparse irregular aggregates up to 1 mm across. There is also a little pyrite, locally in subhedral grains up to 0.4 mm across.

Mineral Mode (by volume): epidote 40%, chlorite 25%, quartz 18%, K-feldspar 5%, sericite, biotite and pumpellyite each 3%, carbonate and FeTi oxide/magnetite each 1% and traces of titanite, leucoxene, zircon, apatite and pyrite.

Interpretation and comment: It is interpreted that the sample represents a porphyritic, fine grained felsic igneous rock, maybe a volcanic or shallow intrusive and containing scattered quartz phenocrysts in a fine grained quartzofeldspathic groundmass. It is strongly to intensely altered. Part of the rock shows indications of thermal metamorphism, causing replacement of the groundmass by finely granular quartz, K-feldspar and biotite, with patchy sericite and a little epidote and chlorite. This zone borders on to the intense alteration zone where the rock is almost completely replaced by fine to medium grained epidote and chlorite, with subordinate interstitial quartz, minor pumpellyite and a little carbonate, magnetite, titanite and pyrite. The intense alteration appears to be retrograde with respect to the biotite-bearing metamorphic assemblage and implies considerable metasomatic introduction of Ca, Mg and Fe.

CETD1 467.7 m PTS

Summary: Compositionally laminated felsic volcaniclastic rock, ranging from matrix-supported coarse lithic-crystal sandstone to finer grained siltstone. Former phenocrystal quartz grains are common and there are scattered lithic fragments, some of which retain porphyritic texture. The rock was probably initially hydrothermally altered, with replacement by fine grained quartz, sericite and chlorite, with a little disseminated sulphides. Deformation was imposed, causing a moderate foliation, defined by preferred orientation of the layer silicates. The rock was later subjected to thermal metamorphism and probable hydrothermal introduction of components, with overprinting and replacement of the deformed assemblage by fine grained randomly oriented biotite, with accompanying magnetite, pyrite and a little chalcopyrite. It is possible that pyrrhotite was originally present, but was replaced by pyrite and marcasite.

Handspecimen: The drill core is composed of a mid- to dark grey, diffusely banded, strongly altered volcaniclastic rock, with relict quartz grains up to 2 mm across. The banding appears to be due to compositional layering, defined by differences in grainsize, colour and mineral proportions. Paler coloured laminae may be rich in quartz and sericite, whereas the darker laminae contain biotite, magnetite and disseminated pyrite. The banding is on a scale of millimetres to centimetres and is at a moderate angle to the core axis. Due to the presence of magnetite, the sample is very strongly magnetic, with susceptibility up to 3040 x 10^{-4} SI units.

Petrographic description

a) Primary rock characteristics: In the section, it is it is apparent that the rock is moderately foliated, strongly altered and recrystallised, but there is moderate preservation of original compositional layering and relict medium to coarse grained clastic texture. There are scattered elongate lithic fragments up to 1 cm across that are altered and recrystallised, but locally preserve relict porphyritic (quartz-phyric) texture. There are abundant disaggregated former volcanic quartz phenocrystal grains up to 3 mm across, along with minor altered feldspar and ferromagnesian/FeTi oxide grains (all of the latter are almost completely obliterated) and a trace of relict zircon. Compositional layers are defined by coarser and finer detrital grainsize, with coarser laminae being of matrix-supported volcaniclastic sandstone type (origjnally silty, tuffaceous matrix and with scattered lithic fragments and quartz phenocrystal grains), intercalated with finer grained volcaniclastic siltstone. The compositional layers are on a scale of millimetres to centimetres; the nature of the detritus indicates a proximal felsic volcanic source.

b) Alteration and structure: The layered volcaniclastic rock underwent hydrothermal alteration and deformation, with metamorphism and associated metasomatic introduction of components following. It is speculated that initial hydrothermal alteration caused replacement of the protolith by fine grained quartz, sericite and chlorite, perhaps with minor disseminated sulphides. A little albite remained at former feldspar sites, although much former feldspar was replaced by quartz ± sericite. Compositional banding was accentuated by some bands being recrystallised to quartz-rich or to layer silicate-rich assemblages. Penetrative deformation was imposed with development of a moderate foliation, best defined in the layer silicate-rich bands and in places wrapping around relict quartz grains. It is interpreted that an event of thermal metamorphism and associated metasomatism occurred, resulting in crystallisation of patchy, but rather abundant fine grained, randomly oriented khaki coloured biotite, disseminations and irregular to elongate aggregates of fine grained magnetite and subordinate pyrite, a little chalcopyrite and trace titanite. It can be implied that Fe, S and Cu could have been metasomatically introduced into the altered and deformed rock; biotite, magnetite and sulphides overprint the earlier sericite-defined foliation.

c) Mineralisation: The sample contains considerable fine grained granular to acicular magnetite as disseminations and irregular to elongate aggregates up to 2.5 mm across. Commonly there is minor associated pyrite and a little chalcopyrite, but the sulphides are also locally concentrated into aggregates and elongate masses up to 1 cm long. Pyrite is fine

grained and in places has intergrown marcasite; it could be implied that these phases could, in part, have replaced earlier pyrrhotite. Magnetite and sulphides appear to have largely formed post-foliation.

Mineral Mode (by volume): quartz 60%, biotite 13%, magnetite 8%, sericite 7%, pyrite 5%, chlorite 3%, albite 2%, chalcopyrite 1% and traces of zircon, titanite and marcasite.

Interpretation and comment: It is interpreted that the sample is a felsic volcaniclastic rock, with compositional banding ranging from matrix-supported coarse lithic-crystal sandstone to finer grained siltstone. Former phenocrystal quartz grains are common and there are scattered lithic fragments, some of which retain porphyritic texture. The rock underwent initial hydrothermal alteration, with replacement by fine grained quartz, sericite and chlorite, and disseminated sulphides. Later deformation caused a moderate foliation, defined by preferred orientation of the layer silicates. The rock was later subjected to thermal metamorphism and hydrothermal introduction of components (Fe, S and Cu), with overprinting and replacement of the deformed assemblage by fine grained randomly oriented biotite, with accompanying magnetite, pyrite and a little chalcopyrite. It is possible that pyrrhotite was originally present, but was replaced by pyrite and marcasite.

Re-examination of thin section of sample CETD1 589.6 m

A re-examination of this thin section was requested to check the status of secondary biotite (and magnetite) development and to comment on whether it could be typical of potassic alteration, rather than due to thermal metamorphism.

The previous summary description of the sample, examined in February, 2009 (Report #544) follows:

CETD1 589.6 m TS

Summary: Metamorphosed and recrystallised coarsely fragmental felsic volcanic, e.g. crystal-lithic-vitric tuff, perhaps of originally dacitic composition. The rock has recrystallised lithic fragments, relict phenocrystal quartz and pseudomorphs after former phenocrystal grains of ferromagnesians and feldspar. In the recrystallised matrix, there are rare relict shapes after former glass shards. The rock was possibly altered and deformed, with development of a weak foliation in the matrix and accompanying development of sericite. Subsequently, a metamorphic overprint caused fine grained recrystallisation of the matrix and former feldspar and ferromagnesian components with replacement by an assemblage of biotite, feldspars, quartz and chlorite, with minor muscovite/sericite, magnetite and traces of carbonate, tourmaline, titanite, allanite, pyrite and chalcopyrite.

Comments

Fine grained, khaki to brown, randomly oriented biotite is common in the sample, occurring as pseudomorphic aggregates at former ferromagnesian mineral sites (including former igneous biotite), at former feldspar sites and in the altered groundmass. Its development overprints (post-dates) a sericite (-chlorite) defined foliation and biotite appears to have replaced sericite and chlorite that had probably developed from prior low grade alteration of the host rock.

Biotite is commonly associated (in places intergrown; elsewhere in the immediate vicinity) with disseminations and aggregates of magnetite and subordinate pyrite, in places with traces of chalcopyrite and green-blue tourmaline. All of the biotite and associated mineral development is pervasive throughout the sample and none could be seen to be controlled by fractures and veining.

The occurrence of biotite could be easily ascribed to metamorphism, e.g. by prograde breakdown of pre-existing sericite and chlorite, due to the attaining of appropriate thermal conditions (e.g. >350°C). The fact that biotite is pervasively developed (in this sample and in most others examined in the present sample suite) suggests a broad thermal imprint has occurred. The local abundance of magnetite and pyrite (and traces of associated chalcopyrite and tourmaline) suggest metasomatic (hydrothermal) introduction of components and the same could be stated for a few samples in the present suite, notably CETD1 467.7 m, where it can be implied that Fe, S, Cu and

perhaps B were introduced into variably altered felsic volcanic/volcaniclastic protoliths. The proposed introduction of components must have been pervasive and not controlled significantly by fracturing and veining (of which little is apparent).

It is suggested that although the association of biotite-magnetite-pyrite can be typical of potassic alteration in relatively mafic host rocks, e.g. in association with porphyry CuAu systems, there is usually a strong indication that alteration overall is controlled by fracturing. Consequently, it is tentatively concluded that the occurrence of biotite in the Cethana rocks is largely of metamorphic derivation (biotite grade metamorphism), but that on a local scale, there must have been hydrothermal introduction of components such as Fe, S (Cu, B). This metasomatism occurred pervasively and apparently not controlled by fracturing. If there is a nearby intrusive source (causing metamorphism and the minor introduction of components) it may not have achieved significant hydrothermal fluid saturation on crystallisation and hence there is little evidence for energetic fluid release (fracture systems) and structurally controlled potassic alteration.