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*file 564  
 Catfish Progress Report*

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### Samples:

20 rock samples from the Catfish Project, for sectioning and petrographic study.

Samples are numbered as follows:

6 Intr	2-STUH	42 ✓ mat ass.	15359 ✓	Gabbro -3
		0067 ✓ marble rhan	15405 ✓	
		0107 ✓ Hw?	15408 ✓	
		0110 ✓ amphib porph flow	15410 ✓	
6 Apl?	2-STUH	0122 ✓	15411 ✓	
		0124 ? Sel + off? pl?	15413 ✓	Int. -3
		0127 ✓ marble	15421 ✓	and. (2)
		0128 ✓ breccia - marble	15730/S ✓	volcanic - granule
		0129 ✓ marble	15731 ✓	
	2-STUH	0130 ? auto brecciated + off	15733 ✓	(2)

Samples 0107, 0124, 0127, 0128 and 0129 were prepared as polished thin sections. The remainder were prepared as conventional thin sections.

### Summary:

The rocks of this suite are of diverse character. They are generally non-foliated, and seem not to be regionally metamorphosed, though some of them show probable thermal effects. Alteration in the volcanic and pyroclastic rocks is predominantly to sericite and, in some cases, to secondary biotite.

4 main groups may be distinguished. Note that some uncertainty exists in the differentiation of intrusive volcanic or pyroclastic character.

**a) Probable Minor Intrusives:**

Samples 0110 and 0122 are porphyritic rocks of amphibole-rich composition. The first is extremely mafic, and best classified as a lamprophyre; the second is of related composition, but contains more plagioclase, and could be classed as a diorite porphyry.

Sample 15408 is a porphyry of andesitic composition. Mafic components show strong alteration to secondary biotite; plagioclase phenocrysts are fresh.

Sample 0107 is of quartzo-feldspathic (dacitic) composition. It shows strong, platy recrystallization, and may be a sheared porphyry. It contains disseminated pyrite.

**b) Probable volcanics:**

Sample 15421 is an andesite showing strong alteration to secondary biotite. It could be fragmental (autobrecciated?).

Samples 15731 and 15733 are porphyritic rhyodacites having sericitized K-spar phenocrysts in a groundmass of quartz and sericitized felsite - probably of original glassy character. They contain traces of tourmaline.

**c) Probable pyroclastics:**

Samples 0124, 15405, 15410, 15411 and 42 are quartz-poor, felsic to intermediate lithic tuffs, or lapilli tuffs, consisting largely of sericitized felsite or altered glass. 1510 contains fine-grained secondary biotite; 15411 shows pervasive tourmalinization; 42 is distinctive for the presence of coarse porphyroblasts of andalusite - possibly the effect of thermal metamorphism.

Sample 0130 may be a breccia of welded tuff fragments or an autobrecciated flow. It is distinct from the previous group in lacking sericite. It contains chlorite and a little epidote and amphibole, and may be of intermediate (andesitic) composition.

**d) Sediments and metasediments:**

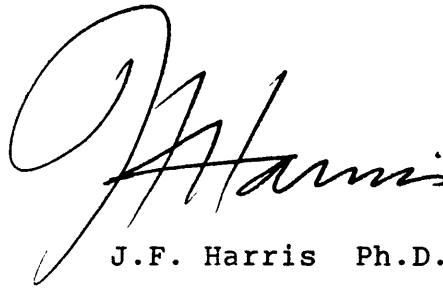
Samples 15359 and 15413 are black carbonaceous siltstones or wackes; the latter sample is a possible slump breccia.

sample 15730/S is a typical greywacke of volcanic lithic clasts and quartz grains.

Samples 0127 and 0129 are magnesian marbles, showing more or less strong development of porphyroblastic tremolite - probably indicative of thermal metamorphism.

Samples 0067 and 0128 are of uncertain origin. They are granoblastic carbonate rocks with pockety segregations of chlorite (or possibly serpentine). The second sample has a similar carbonate composition (mixed calcite and ankerite) as the previous group, and contains accessory tremolite - suggesting a kinship with the tremolite marble group. In Sample 0067 the carbonate is entirely calcite. The morphology of the chlorite (serpentine) suggests the possibility that it may represent the total alteration of skarnic forsterite aggregates in a marble.

Individual petrographic descriptions and illustrative photomicrographs are attached.

A handwritten signature in cursive script, appearing to read "J.F. Harris". The signature is written in black ink and is positioned above the typed name and title.

J.F. Harris Ph.D.

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## Estimated mode

Sericite	45
Chlorite	10
Plagioclase	18
Quartz	1
Andalusite(?)	18
Apatite	trace
Opaques	8

Macroscopically this is a speckled rock of apparent porphyritic aspect. The slide includes a small area of a fine-grained, streaky unit - in apparent bedded(?) contact with the speckled lithotype.

In thin section the rock is found to consist predominantly of minutely fine-grained sericite, as a non-foliated, felted aggregate of grain size 1 - 10 microns.

Accessory constituents are intimately intergrown chlorite, felsitic plagioclase and disseminated, sub-opaque and opaque material.

A diffuse, cryptofragmental or porphyritic texture, on a scale of 0.1 - 1.0mm, is defined by patchy variations in the proportions of intergrown chlorite and felsite in the sericite. The felsite may represent remnants of an original plagioclase-rich volcanic or tuff, now largely converted to sericite.

The disseminated opaques - as granules 5 - 20 microns in size, aggregating to equant grains of 100 microns or more - tend to form patchy clusters which locally emphasize the relict volcanic texture. They are probably mainly pyrrhotite.

Apatite is seen as occasional individual, tiny subhedra. Quartz forms a few tiny pockets and rare, fragment-like patches of chert-like aggregate.

The speckled appearance of the rock, on the macroscopic scale, is found to be the result of porphyroblastic development, in the form of diffuse to sharply prismatic areas, 0.2 - 1.5mm in size, of a moderate relief, low-birefringent mineral thought to be andalusite. In part, these are aggregates of minute granules, but locally they develop optical homogeneity.

The phase making up one end of the slide is of generally similar character to the dominant lithotype, except that it lacks andalusite porphyroblasts. It is also notably less sericitized, and is composed largely of felsite. Opaques in this area tend to segregate as sub-prismatic patches and rimming forms of pseudomorphous aspect.

Sample 42 cont.

The contact between the two phases is demarked by a streaky, foliated, sericite-rich zone.

The sample is an altered andesite - possibly a tuff.

The presence of andalusite porphyroblasts is suggestive of a thermal (contact metamorphic) overprint on the andesite, resulting from proximity to an intrusive body.

## Estimated mode

Serpentine	44
Chlorite	1
Carbonate	50
Sericite	3
Pyroxene	trace
Opagues	2

This rock is a streaky/pockety intergrowth of two main constituents - a carbonate and a fibrous-textured mineral having the aspect of serpentine.

X-ray diffraction checks show that the carbonate is entirely calcite. The identity of the other component remains uncertain; it gives a very subdued XRD response which, on balance, is a better match for serpentine than chlorite.

The calcite is in the form of an even, polygonal mosaic, of grain size 0.1 - 0.4mm.

The serpentine occurs as extensive, sharply defined, irregular patches of pseudo-crustified/cellular to spherulitic habit. Occasional inclusions of calcite are seen within the serpentine masses, and there is a tendency for mutual intergrowth in the contact zones. Serpentine also occurs as small, interstitial pockets within the carbonate mosaic.

Opagues occur as fine, duty disseminations and cellular networks in the serpentine, and as granular clusters in the carbonate - especially in association with some localized, elongate zones of rather coarse, well-formed sericite or muscovite flakes.

A single, small grain of fresh pyroxene was seen within carbonate.

The origin of this rock is obscure. It appears to be a marble. The serpentine could possibly be a pseudomorphic replacement (total alteration) of clumps of original skarnic forsterite, or some other magnesian silicate.

## Estimated mode

Plagioclase	56
Quartz	22
Sericite	17
Rutile	trace
Pyrite	5

This is a rock of distinctive, sinuously laminar texture.

It is composed principally of fresh plagioclase with accessory quartz. The fabric appears strongly recrystallized, and consists of an aggregate of more or less strongly elongate, crenulate-margined grains, 20 - 200 microns in size. Coarser, sub-prismatic (relict primary) plagioclase grains, to 1.0mm in size, occur as scattered individuals, generally oriented parallel to the marked foliation, and as augen-like, or blocky kernels within the finer, recrystallized felsite.

Quartz occurs in indeterminate accessory proportions throughout the recrystallized plagioclase matrix, and also concentrates as occasional irregular clumps and lenses.

Sericite mainly occurs in strikingly segregated manner, as slightly sinuous schlieren, 0.1 - 1.0mm in thickness, and spaced 0.3 - 2.0mm apart. These are composed of lines of well-crystallized flakes, grading to minutely foliated wisps. Minor amounts of sericite are also seen as small, discontinuous, intergranular wisps within the feldspathic matrix.

Pyrite - apparently without any associated accessory sulfides - occurs as strings of irregular/elongate to subhedral grains, 20 - 200 microns in size - locally aggregating to lenses of 2mm or more in length. These are closely associated with the micaceous schlieren, and show intimate textural intergrowth with the sericite flakes.

This rock is of uncertain origin. It is clearly of igneous ancestry, and may be an intensely sheared and extensively recrystallized dacite porphyry, or possibly a crystal tuff. The striking freshness of the plagioclase (having the composition of oligoclase) favours the former possibility.

The sulfides appear to have been sheared and recrystallized along with the matrix.

## Estimated mode

Amphibole	82
Plagioclase	10
Epidote	3
K-feldspar	1
Carbonate	trace
Sphene)	3
Rutile)	
Opaques	1

This is a mafic igneous rock of prominently porphyritic texture.

Phenocrysts make up about 50% of the rock. They consist predominantly of sharply angular (equant/prismatic) masses of felted/fibrous, pale green to brownish amphibole, 0.3 - 3.0mm in size, sometimes with minor included epidote and opaques. These are clearly pseudomorphs after some original mafic silicate. No actual remnants of this survive, and distinctive crystal outlines are seldom seen; it most probably originated as hornblende.

Less abundant, generally smaller, elongate, prismatic phenocrysts of plagioclase are also seen. These tend to show rather diffuse outlines, and appear partially assimilated by the groundmass.

The latter consists largely of a minutely felted mass of colourless, acicular, secondary-type amphibole, as randomly oriented, interlocking needles, 10 - 100 microns in size. Tiny granules of sphene and/or rutile are evenly disseminated accessories in the groundmass, and there is probably also an interstitial low-birefringent component which may be felsitic plagioclase or glass.

Scattered prominent clumps of granular/radiate epidote, rimmed by, or intergrown with, fine-grained K-feldspar and traces of carbonate, have the appearance of amygdules. A few of these show more angular form, suggesting that they may, in fact, be a type of altered (feldspar?) phenocryst.

The slide is cut by a sharply demarked microfracture or fault showing slight lateral displacement.

This rock could be a form of altered porphyritic volcanic, but its strongly amphibolitic composition and textural features suggest that it is most likely a type of lamprophyre.



## Estimated mode

Amphibole	52
Plagioclase	32
K-feldspar	8
Sericite	3
Epidote	4
Sphene	trace
Opagues	1

This is a rock of somewhat similar composition to the previous sample (0110). However, it has a distinctly higher content of feldspar and lacks the extreme textural bimodality of the previous sample.

Phenocrysts make up a high proportion of the rock. They are of two main kinds. The coarsest (up to 6mm in size) are equant/angular, often 6-sided crystals, now totally pseudomorphed by felted/fibrous, secondary-type, green amphibole - often intergrown with accessory proportions of K-feldspar and epidote, and sometimes with fine-grained opaques. These pseudomorphs probably originated as euhedral hornblende.

The other type of phenocryst consists of elongate, prismatic grains of plagioclase, 0.2 - 2.0mm in size. These are generally more or less turbid as a result of pervasive alteration to minutely fine-grained sericite and clays. The feldspar prisms show a crudely tangential orientation around and between the coarser amphibole pseudomorphs.

A matrix or interstitial phase, composed of minutely felted amphibole with indeterminate proportions of felsitic plagioclase and minor specks of sphene or rutile, constitutes the remainder of the rock - occupying the spaces between the close-packed phenocrysts. The mineralogical similarity between the groundmass and the altered mafic phenocrysts, plus the turbid, indistinct nature of the plagioclase, gives the rock a very diffuse, ill-defined appearance in thin section.

The slide is cut by a network of hairline veinlets of fibrous amphibole (paler in colour and better crystallized than the groundmass amphibole).

This rock could be classified as a diorite porphyry or a type of lamprophyre.

**SAMPLE 0124**

**FELSIC TUFF**

N mtn N side  
Aplite?

Estimated mode	
Plagioclase	40
Quartz	5
K-feldspar	2
Sericite	38
Chlorite	3
Carbonate	6
Sub-opaque dust	2
Pyrite	4

The cut-off block of this sample has the appearance of a coarse, matrix-less breccia in which the constituent fragments - of a fine-grained, porcellanous rock - are distinguished by various degrees and types of alteration. Fine-grained volcanic and/or pyroclastic textures are distinguishable within the coarse breccia fragments.

In thin section the rock is found to consist predominantly of cryptocrystalline felsite and sericite. The former constitutes a matrix to abundant vari-sized altered feldspar crystal clasts and lithic fragments. These are mainly in the size range 0.3 - 1.0mm, but a few lithic clasts, up to 5mm or more, are also present.

The crystal clasts are totally converted to minutely felted sericite, with minor wisps and patches of carbonate. A few equant crystal clasts of quartz are also seen.

The lithic clasts are also composed predominantly of minute fine-grained sericite and, in many cases, have the ragged, streaked-out appearance and crypto-pumiceous texture of original glass. A few of the coarser fragments are recognizably porphyritic, and contain small phenocrysts of quartz and partially unaltered plagioclase, sometimes in a devitrified mosaic-textured glass matrix.

The rock contains irregular pockety and wispy segregations of quartz, chlorite and K-feldspar (in various proportions). It is also distinguished by a substantial content of disseminated pyrite. The latter occurs randomly, without apparent structural control or consistent relation to fragments or matrix, as irregular to subhedral, sometimes poikilitic grains, 0.02 - 1.0mm in size, locally coalescing to irregular clumps. Sometimes the pyrite is associated with the quartz/chlorite pockets, but this is not a consistent feature.

**SAMPLE 0127**

**TREMOLITIZED MARBLE**

**Ls**

**Estimated mode**

Carbonate	72
Tremolite	27
Chlorite	1

This is an altered marble of simple composition.

The portion sectioned includes two distinct assemblages in apparent replacement contact.

About 40% of the slide consists of a homogenous, fine-grained carbonate aggregate, of grain size 20 - 150 microns. The remaining 60% is a skarn-like assemblage of fibrous/acicular tremolite, intimately intergrown, in sheaf-like, skeletal, porphyroblastic mode, with coarser, sparry-textured carbonate.

The tremolite-carbonate phase has apparent inclusions (unreplaced remnants?) of the fine-grained marble, and the latter is penetrated - at the irregular contact - by diffuse veniform apophyses of very fine-grained tremolite (presumably representing the first stages of an advancing replacement front).

XRD analysis shows the presence of major proportions of both calcite and ankerite. Judging from the relative reactivity to dilute acid in the cut-off block, the fine-grained aggregate is predominantly ankerite, and the coarser, invasive phase (with tremolite) is calcitic.

The only other constituent is chlorite, as a few radiate/fibrous-textured pockets and diffuse streaks within the altered marble close to the contact.

## Estimated mode

Carbonate	58
Tremolite	8
Chlorite	28
Biotite	3
Talc(?)	1
Sphene)	1
Rutile)	
Pyrite	1
Pyrrhotite	trace
Chalcopyrite	trace

This is a heterogenous-textures rock of metasomatic aspect. It shows some similarities to Samples 0127 and 0067.

Macroscopic examination of the cut-off block, or the slide, reveals a pockety, concentrically-zoned distribution of several different phases, possibly suggestive of cementation and replacement of an original breccia.

The relationships of one phase to another are obscure. The principal constituents are as follows:

- a) varigranular, micritic to coarsely recrystallized carbonate, locally strongly clouded with micron-sized opaque dust (mainly pyrrhotite, partly altered to Fe oxides) and/or speckled with individual euhedral pyrite grains, 0.02 - 0.3mm in size.
- b) inclusion-free carbonate, with varying proportions of randomly intergrown, acicular tremolite. This phase contains rare individual specks of chalcopyrite.
- c) felted chlorite, locally grading to pale brown biotite (phlogopite). Fine flecks and granules of rutile and sphene are a common accessory in this phase.

These three components occur as more or less sharply defined, concentric bands, in the order listed, and locally show complex intermingling.

Minor patches of possible felted talc are seen in the carbonate.

XRD analysis shows the presence of calcite and somewhat less abundant ankerite. By analogy with Sample 0129, the type a) carbonate is probably the ankerite, and the type b) carbonate is the calcite.

This rock is of uncertain origin, but is probably a form of altered marble (c.f. Sample 0067).

## Estimated mode

Carbonate	84
Tremolite	16
Chlorite	trace
Rutile)	trace
Sphene)	
Pyrite	trace
Arsenopyrite	trace
Pyrrhotite	trace
Limonite	trace

This is another tremolite-bearing marble, clearly of related type to Sample 0127.

It consists predominantly of a rather homogenous, very fine-grained, anhedral aggregate of carbonate, of grain size 10 - 50 microns. XRD analyses show that this consists of a mixture of ankerite and somewhat less abundant calcite.

The micritic carbonate aggregate is traversed by a diffuse network of more or less abundant veniform and pockety zones of slightly coarser carbonate with intergrown, fine-grained acicular tremolite. One localized streaky segregation of felted chlorite was also seen. The veniform carbonate is reactive to dilute acid, and appears to be the calcite - the fine-grained matrix being ankeritic.

Rare elongate clumps of sparry, actinolite-free carbonate contain fine-grained disseminated sulfides (pyrite, arsenopyrite and pyrrhotite - partially oxidized).

**SAMPLE 0130**

**INTERMEDIATE TUFF**

Arg? intbed vs.  
reworked volcanic breccia

**Estimated mode**

Plagioclase	68
Quartz	3
Chlorite	18
Epidote	2
Tremolite	3
Sphene)	5
Leucoxene)	
Pyrite	1

This is a fine-grained rock of uncertain origin. It has an ill-defined, patchy, cryptofragmental texture, and is probably a form of autobrecciated, devitrified, glassy volcanic or breccia of welded tuff.

It is made up essentially of minutely fine-grained felsitic plagioclase, of grain size 5 - 20 microns. This contains more or less abundant flecks and granules of accessory chlorite and sphene/leucoxene (and possibly some cryptocrystalline epidote). The distribution of the accessories defines a small-scale, wispy foliation - resembling flow-banding or the texture of a welded tuffite.

A fragmental structure, on the scale 0.5 - 10.0mm or more, is distinguishable by virtue of differing directions of the wispy foliation in adjacent areas. The rock appears to be a breccia of close-packed, non-matching, angular fragments of the same rock type (autobreccia?).

Occasional angular clasts or pockets of cherty quartz are seen.

The rock is cut by a sparse network of hairline veinlets and streaky gash-like segregations of fibrous tremolite, and of felted chlorite.

Sporadic irregular clusters of fine-grained sulfides (apparently mainly pyrite) are also seen. These show no consistent relationship to the fragmental structure or the microfractures.

## Estimated mode

Quartz	9
Plagioclase	6
Sericite	8
Sericitized felsite	44
Carbonaceous material	33
Pyrite	trace

This rock is a typical example of a fine-grained carbonaceous siltstone or argillite.

Its appearance in thin section is dominated by the abundant, pervasive opaque pigmentation. Under high magnification this can be seen to constitute a wispy, micro-foliated matrix, separating and wrapping around individual tiny clasts of more or less intensely sericitized felsite and of less abundant crystalline plagioclase, quartz and discrete sericite flakes.

The constituent clasts are in the size range 20 - 150 microns, and are equant/angular to somewhat elongate in form.

A few laminae or lenses of slightly coarser, carbon-poor sediment occur. These consist largely of quartz grains in a felted sericite matrix. There are also a few threadlike, concordant wisps of pyrite.

The rock is cut by a few oblique microshears which are the locus of redistribution and concentration of carbonaceous material.

Overall, this is a rather homogenous, undisturbed sediment, showing well-preserved, primary, clastic textures.

**SAMPLE 15405**

**SERICITIZED LITHIC TUFF**

*fel tuff w  
matic lap.*

Estimated mode

Fragments	Sericite	54
	Plagioclase	1
	Apatite	trace
Matrix	Chlorite)	40
Cryptocrystalline material)	Sub-opaque dust	5

Low-power examination of the etched cut-off block clearly indicates the fragmental character of this rock. Sub-rounded to irregular-shaped, lithic clasts, up to lapilli of 8mm or more in size, make up >50% of the rock. The majority of these are of ragged, streaked-out, or ripped-off form - as in glass fragments still soft at the time of accumulation - and show a weak tendency for a preferred elongation.

In thin section these clasts are found to consist essentially of structureless, minutely felted sericite - almost certainly representing altered glass. Some exhibit pumiceous or shard-like fabrics. The fragments sometimes contain small feldspar phenocrysts which are also totally sericitized, and patches of low birefringent material which may be chloritic, whilst a few contain rare subhedral phenocrysts of fresh plagioclase, to 1mm in size. Tiny euhedral crystals of apatite are also seen.

The fragments are set in a featureless, cryptocrystalline, sub-opaque matrix. This is of similar appearance to the fragments, but of lower birefringence, and more or less densely dusted with micron-sized sub-opaque material. It possibly contains an indeterminate proportion of chlorite.

The sub-opaques (rutile) locally concentrate as rare, dense clusters of fragmental aspect.



## Estimated mode

Plagioclase	64
Sericite	2
Secondary biotite	28
Secondary amphibole(?)	2
Rutile)	4
Opaques)	

This is a rock of notably different type to any previous samples of the suite. It is a coarsely porphyritic volcanic or minor intrusive of probable andesitic composition, in which plagioclase phenocrysts are notably fresh, but mafics are totally altered - with development of a distinctive, red-brown, secondary-type biotite.

Phenocrysts make up 50 - 60% of the rock. They are of two kinds. The commonest consist of subhedral prismatic plagioclase crystals, 1 - 6mm or more in size. These are often well-twinned (indicating a composition of andesine) sometimes show fracturing and local granulation. They are generally fresh, but occasionally show veining and partial replacement by minutely felted sericite and/or secondary biotite.

The other phenocryst type is now totally converted to compact or diffuse masses of minutely felted, red-brown biotite. In a few cases, these show cores of similarly-textured, pale green, secondary-type amphibole.

These biotitized masses presumably represent original mafic phenocrysts, though their form is generally indistinct and sometimes streaked-out. This is possibly the result of a tendency for the original mafic phenocrysts to cluster, combined with more or less extensive dispersion and redistribution of the secondary biotite. This fills microfractures, and forms diffuse, pervasive replacements and microbreccia fillings in plagioclase phenocrysts and the groundmass.

The groundmass is a minutely fine-grained meshwork to sub-trachytic aggregate of felsitic and microlitic plagioclase, with interstitial altered mafics (now represented by red-brown biotite) and abundant, disseminated granules of rutile and opaques. Groundmass grain size is in the range 10 - 100 microns.

**SAMPLE 15410****LITHIC TUFF****Estimated mode**

Sericite	42
Felsite	35
Secondary biotite	20
Quartz	trace
K-feldspar	trace
Sub-opaque dust	3

This sample is unambiguously identifiable as a felsic to intermediate lithic tuff. The etched cut-off block clearly reveals the presence of abundant, equant to somewhat elongate, ragged-shaped clasts, ranging up to lapilli of 8mm or more. The majority of the clasts are in the size range 0.2 - 2.0mm.

In thin section the clasts are found to be composed of more or less strongly sericitized, cryptocrystalline felsite. Some of the larger clasts are recognizably microporphyrific, with partially sericitized plagioclase phenocrysts to 0.5mm or more in size; others show streaky and pellety textures, and clearly originated as glass; and a few appear to be refragmented tuffs.

Clasts make up some 80% of the rock, and range down to 0.05mm or less in size, the smaller lithic detritus being packed interstitially between the coarser fragments.

A matrix phase - presumably representing finely comminuted glass dust - cements the whole aggregate. It is characterized by a high content of micron-sized opaques and sub-opaques, and of diffuse orange-brown biotite.

The same, minutely-felted, orange-brown biotite (similar to that seen in Sample 15408) is also seen as patches (altered mafics?) in some of the porphyritic clasts. Some smaller clasts are composed entirely of this material (biotitized glass?).

Rare, tiny clasts of quartz and chert, and a few individual crystal clasts of plagioclase, are also present.

The rock shows a weak foliation which clearly represents original bedding. It is remarkable for its clearly defined, primary fragmental features and lack of any apparent recrystallization.

## Estimated mode

Sericite	80
Felsite	5
Chert?)	5
Albitite?)	5
Chlorite	5
Tourmaline	2
Rutile)	3
Leucoxene)	3
Limonite	trace

This is clearly another pyroclastic rock - though with less well defined fragment outlines than in the previous sample. The constituent clasts appear to be predominantly much larger than in 15410 - commonly being in the range 3 - 15mm or more. The majority of them display a streaky, flecked macroscopic texture.

In thin section the clasts are found to consist essentially of minutely felted sericite, with wisps and patches of similar-textured but lower birefringent material which may be of more felsitic and/or chloritic composition. The distribution of the more and less sericitic material within the clasts is a patchy/streaky contorted one, suggestive of original pumiceous, glassy character.

Wisps and irregular pockety concentrations of micron-sized opaque/sub-opaque material occur throughout - probably mainly in an interclast relationship.

One large sub-rounded clast is composed of a microgranular mosaic of chert (or possibly albite), and similar material is also seen as small, diffuse shreds elsewhere in the slide.

Interclast contacts tend to be defined by local microshears, with oriented sericite and concentrations of chlorite and opaque dust.

A distinctive feature, not seen in previous samples, is the presence of pervasive tourmalinization. This is manifested as tiny, disseminated, acicular crystals, up to 0.1mm in length, often as radiate sheafs. The tourmaline needles are seen randomly within the body of the sericitized clasts, and tend, in particular, to concentrate in the shear-like interclast wisps.

**SAMPLE 15413 SLUMP BRECCIA(?) OF CARBONACEOUS WACKE**

Estimated mode

Sericite	28
Plagioclase)	10
Felsite)	
Quartz	8
Chlorite(?)	38
Carbonaceous matter	16

Macroscopic features indicate that this rock is another fragmental product. However, its overall black colour suggests carbonaceous character, which appears more consistent with a sedimentary rather than a pyroclastic origin. The cut-off block includes several coarse, angular fragments of a platy lithotype which has the aspect of a black shale, and suggests possible affinities with Sample 15359.

In thin section the rock is seen to be an aggregate of fragments of widely different sizes, ranging from 0.05 - 10.0mm or so.

Overall it has the appearance of a polyolithic wacke composed of close-packed, angular to ovoid clasts of cryptocrystalline/felted sericite and chlorite, and/or felsitic material, plus notable amounts of mineral clasts of quartz and chert. These are set in a minimal matrix of chloritic material with varying proportions of pervasive opaque (carbonaceous?) dust.

Some of the larger clasts are of ragged shape and streaky/pellety texture, and clearly originated as glass.

The coarsely fragmental structure is defined by areas of the wacke lithotype showing different average grain size and proportions of opaque matter. Some of these are highly enriched in the latter component - the angular, shaly fragments referred to in the macroscopic description being essentially totally opaque, with pellety patches of felted chlorite.

The rock appears to be a melange - possibly of slump origin - of carbonaceous shale, volcanic wacke or tuff, and chert.

## Estimated mode

Plagioclase	43
Chlorite	10
Secondary biotite	40
Quartz	3
Rutile)	2
Leucoxene)	
Carbonate	trace
Opaques	2

This sample does not show clearly defined features on the macroscopic scale. A possible cryptofragmental texture, defined by a network of irregular unetched wisps in the predominantly strongly etched matrix, is distinguishable in the cut-off block.

In thin section the rock is found to be distinguished by its high content of the red-brown, minutely felted, secondary-type biotite seen in some other samples of the suite (notably 15408).

More or less compact, aggregated, clumpy to diffuse areas of the fine-grained biotite alternate patchily, on a scale of 0.1 - 0.5mm, with a fine-grained volcanic material consisting of felsitic plagioclase, chlorite and micron-sized rutile/leucoxene and occasional recognizable plagioclase phenocrysts to 0.5mm in size.

The nature of this intergrowth is unclear. It may represent a fragmented andesitic volcanic, cemented and diffusely pervaded by the biotite. Alternatively, it could be a more or less homogenous volcanic in which the biotite patches and streaks represent totally altered pseudomorphs of semi-coalescent clumps of small mafic phenocrysts. Some diffuse dispersion of the secondary biotite may also have taken place.

Other constituents are quartz, as semi-continuous hairline veinlets, scattered tiny grains and small pockety segregations - presumably indicative of incipient silicification.

Opaques (apparently mainly pyrite or pyrrhotite) are sometimes associated with the diffuse threads of quartz, but most commonly show a distinctive mode of occurrence as dense clusters of tiny grains concentrated in discrete, rounded to sub-prismatic patches of minutely microgranular quartz. Traces of carbonate are sometimes intergrown, and one sulfide cluster is located within a patch composed totally of fine-grained carbonate. These features may represent centres of alteration, or could possibly be amygdules.

## Estimated mode

Plagioclase)	62
Felsite)	
K-feldspar	1
Quartz	16
Biotite	18
Rutile	2
Carbonaceous matter	1
Pyrrhotite	trace

This is an even-grained rock having the macroscopic appearance of a bedded clastic sediment.

This impression is confirmed in thin section, where the rock is seen to be a typical greywacke composed largely of volcanic lithic clasts.

The slide includes two bedded units in contact. In the coarser one the clasts range up to 0.5mm in size, whereas in the finer they are seldom more than 0.1mm. The two units are separated by a thin sinuous intercalation of carbonaceous siltstone.

In the (predominant) coarser wacke unit, the clasts are mainly composed of cryptocrystalline felsitic material. In some cases this may contain indeterminate proportions of intergrown chlorite. The felsitic clasts show varying degrees of pervasive alteration to minutely fine-grained, felted, orange-brown biotite. This also tends to concentrate as an interclast network, and, in redistributed form, as discordant streaks and microshears, often containing fine-grained pyrrhotite.

A proportion of the clasts are composed almost entirely of felted biotite, sometimes with disseminated granules of rutile; these presumably represent a somewhat more mafic form of altered aphanitic volcanic.

Quartz is a relatively prominent constituent, as individual angular to sub-rounded clasts, 0.0 - 0.5mm in size, and occasional microgranular lenses. The quartz clasts (and rare crystalline plagioclase clasts) are randomly and rather evenly scattered through the aggregate of close-packed, somewhat ill-defined, partially elongate lithic clasts.

The finer-grained siltstone unit is of similar mineralogy, but the shapes of individual lithic clasts are seldom distinguishable, and the rock consists of small quartz clasts scattered through a streaky, turbid, diffusely biotitized matrix of felsite. The latter appears to be of distinctly potassic composition (see stained cut-off block), compared with the dominant material of the coarser unit.

## Estimated mode

Plagioclase)	45
Felsite)	
Quartz	14
K-feldspar	5
Sericite	30
Biotite	6
Tourmaline	trace
Rutile	trace
Apatite	trace
Opaques	trace

The matrix texture of this rock, as revealed in thin section, somewhat resembles that of a fine-grained wacke - being an even, diffusely microgranular aggregate of quartz, plagioclase and sericitized felsite, on the scale 50 - 100 microns. However, this texture is also characteristic of the devitrified groundmass of many felsic volcanics. The presence of prominent, euhedral, phenocryst-like forms in the stained cut-off block favours the latter possibility.

The phenocrysts, 0.3 - 2.0mm in size, are composed of potassic feldspar - now strongly altered to patches and networks of minutely felted sericite.

The rock also contains smaller, sub-prismatic phenocrysts of felted, brown, secondary-type biotite - often with included fine-grained rutile or opaques. These are presumably pseudomorphs of some primary mafic silicate.

Secondary biotite also occurs, to a minor degree, in dispersed form throughout the matrix.

Tourmaline is a notable trace accessory, as sporadic small clumps and radiate sheafs. These are sometimes associated with biotite/rutile patches (mafic pseudomorphs) or with sericitized glass remnants.

The rock includes some ragged, wispy patches of sericite, which appear to be xenoliths of altered pumiceous glass. Alternatively, they may represent undevitrified (possibly autobrecciated) remnants of the originally glassy matrix.

A weak tendency to preferred orientation is exhibited by the biotitized phenocrysts, sericitized glassy xenoliths and a few diffuse laminar quartzose zones. These are probably flow-related features in what is most likely an altered rhyolitic volcanic.

There is no direct evidence favouring a tuffaceous character for the rock.

## Estimated mode

K-feldspar	6
Sericite	22
Plagioclase)	46
Felsite)	
Biotite	8
Quartz	18
Tourmaline	trace
Apatite	trace
Opagues	trace

This is a macroscopically similar rock to the previous sample (compare the stained cut-off blocks).

The similarity is confirmed in thin section, where the rock is seen to consist predominantly of an equigranular matrix of diffusely sericitized felsite, evenly sprinkled with flecks and small elongate clumps of quartz, 20 - 150 microns in size.

A feature of the matrix, not seen in Sample 15731, is an abundance of tiny, fluidally-oriented, microlitic forms, apparently composed mainly of biotite.

The macroscopically prominent K-feldspar phenocrysts are 0.3 - 3.0mm in size, and show strong diffuse alteration to minutely felted sericite. A minor proportion of altered mafic phenocrysts is also present, now pseudomorphed by felted secondary biotite.

A few of the biotite clumps have intimately intergrown opaques and clusters of acicular green tourmaline.

Tiny elongate euhedra of apatite are a notable trace accessory.

A weak, flow-related, preferred orientation is apparent in the distribution of phenocrysts, and as streaky mineralogic segregations and a sub-trachytic microlitic fabric in the groundmass.

This rock appears to be a pervasively sericitized, porphyritic, felsic volcanic, having a devitrified glassy groundmass. It is of rhyodacite composition.



## PHOTOMICROGRAPHS

All photos are by cross-polarized transmitted light, at a scale of 1cm = 0.17mm, except where otherwise stated.

### a) INTRUSIVES

**SAMPLE 0110: Neg. 157-8: Lamprophyre.** Typical field, showing mafic phenocrysts pseudomorphed by secondary amphibole with opaque inclusions (grey-green and yellow-brown flaky masses; bottom left, bottom centre right); elongate prismatic feldspar phenocrysts (grey; lower centre, right); and clump of granular epidote (bright colours; centre) partially rimmed by K-feldspar (grey). Groundmass is composed largely of felted amphibole, low-birefringent cryptocrystalline material and sub-opaque granules.

**SAMPLE 0122: Neg. 157-9: Lamprophyre.** Majority of field consists of part of a large altered mafic phenocryst, pseudomorphed by fibrous secondary amphibole (yellow brown) with intergrown K-feldspar (grey) and opaque granules (black). Lower part of field includes turbid (saussuritized) prismatic plagioclase phenocrysts in a matrix of felted secondary amphibole.

**SAMPLE 15408: Neg. 157-16: Andesite porphyry.** Shows fresh plagioclase phenocrysts (grey, twinned) in a groundmass rich in secondary biotite (red-brown) and rutile/opaque, showing a sub-trachytic fabric of plagioclase microlites. Clumpy concentrations of red-brown felted biotite (at upper left and top right) are probably altered mafic phenocrysts.

**SAMPLE 0107: Neg. 157-7: Sheared felsic porphyry.** Shows strongly foliated (sheared) fabric consisting of schlieren of sericite (yellow-blue-green) in platy alternation with recrystallized/granulated quartz and fresh plagioclase (white-grey). Field includes two relict plagioclase phenocrysts (upper left; centre bottom). Note concordant lens of pyrite grains (opaque, black).

### b) VOLCANICS

**SAMPLE 15421: Neg. 157-21: Biotitized andesite.** Typical field showing patchy alternations of fine-grained andesite (grey, flecked areas e.g. top centre, bottom right) and concentrations of minutely felted biotite (orange brown). Note some diffuse pervasion of the andesite matrix areas by the fine-grained secondary biotite. Field also includes two amygdale-like patches of microgranular quartz (white-grey) with cores of aggregated pyrite granules (opaque, black).

**SAMPLE 15731: Neg. 157-23: Rhyodacite.** Typical field, showing matrix of sericitized felsite (speckled) with diffuse flecks and clumps of quartz (white-grey). Field includes a clump of brown biotite (upper right) probably representing an altered phenocryst. Minutely fine-grained brown biotite is also seen in dispersed form throughout the matrix.

**SAMPLE 15733: Neg. 157-24: Rhyodacite.** Similar quartz-flecked felsite matrix (devitrified glass) to 15731. Field includes parts of two diffusely sericitized K-feldspar phenocrysts (top right, bottom right). These are much less clearly defined in thin section than on the macroscopic scale. Brown area at upper left is a mafic phenocryst pseudomorphed by felted secondary biotite and opaque granules. Note smaller clumps and diffuse dustings of biotite throughout the matrix.

### c) PYROCLASTICS

**SAMPLE 42: Neg. 157-4: Altered tuff.** Note relict fragmental or porphyritic textures (lighter patches and wisps) in matrix of minutely felted sericite dusted with micron-sized opaques. Field includes several of the prominent phenocryst-like forms which are thought to be porphyroblasts of andalusite. These are predominantly made up of aggregates of minute spongy granules which appear sub-opaque in thin section. Some better crystallized, more transparent patches are also present. Note how the andalusite prisms are clearly developing in situ in the matrix - the patchy fabric of which can still be distinguished within them

**SAMPLE 15411: Neg. 157-18: Altered lapilli tuff.** Shows large, altered glassy clasts with streaky/flecked pumiceous fabric defined by more sericitic (lighter coloured) and more chloritic (darker) material, and wisps of sub-opaque dust. Opaque material (probably mainly rutile) tends to concentrate interstitially to the clasts (e.g. centre, top).

**SAMPLE 15411: Neg. 157-19:** Plane polarized light: Scale 1cm = 85 microns. Higher magnification to show acicular tourmaline crystals (pale grey-green; some examples circled). Note concentration of tourmaline and opaques in crenulate microsheared zones demarking clast boundaries.

**SAMPLE 15410: Neg. 157-17: Lithic tuff.** Typical field showing sharply defined lithic clasts in a matrix loaded with fine-grained sub-opaques and secondary biotite (brownish). Clast at bottom right is recognizably porphyritic. Clast at top left is of sericitized felsite.

**SAMPLE 15405: Neg. 157-15: Sericitized lithic tuff.** Shows ill-defined fragmental textures in minutely fine-grained sericitic and/or chloritic felsite. Field includes some small, intensely sericitized clasts or phenocrysts (whitish) and a few tiny fresh feldspar grains (grey). Note general streaky appearance suggestive of original glassy character.

**SAMPLE 0130: Neg. 157-13: Intermediate tuff.** Shows coarse, angular fragmental, autobrecciated structure in cryptocrystalline felsite with abundant chlorite and sub-opaques (dark). Note weak, foliated fabric within the coarse fragments; this may be a relict welded tuff texture. Field includes a few flecks or pockets of quartz (white).

**SAMPLE 0124: Neg. 157-10: Felsic tuff.** Typical field, showing small sericitized clasts (lighter brownish grey) in matrix of felsite (speckled darker grey). Field includes individual grains and clumps of quartz (white; grey) and disseminated pyrite (opaque, black) - in part associated with a clump of quartz (top).

#### d) SEDIMENTS

**SAMPLE 15359: Neg. 157-14: Black argillite.** Typical field showing small grains of quartz and plagioclase (white, grey) and flakes of sericite (pink, blue), together with felsitic clasts (speckled, barely distinguishable from the dark background), set in a pervasive matrix of opaque, probably carbonaceous material (black). Note weak but distinct foliation.

**SAMPLE 15413: Neg. 157-20: Breccia of carbonaceous wacke.** Plane polarized light. Shows clasts of quartz or chert (white) and felsitic/chloritic material (darker, speckled) in a chloritic matrix more or less densely impregnated with opaque (carbonaceous?) matter. Note concentration of opaque material (left) separating coarse blocks of the carbonaceous wacke.

**SAMPLE 15730/S: Neg. 157-22: Greywacke.** Typical wacke of angular quartz grains (white, grey) and rather even-sized, close-packed felsitic lithic clasts (speckled). Note that many of the lithic clasts are more or less strongly enriched in minutely fine-grained felted brown biotite.

**SAMPLE 0128: Neg. 157-12: Altered marble.** Field shows banded/crustified zones of minutely fine-grained brown carbonate with disseminated pyrite (bottom left); recrystallized, somewhat flattened mosaic of carbonate with acicular/skeletal tremolite (colours; centre); and fine-grained, felted chlorite (blue-black, with minor brownish biotite; upper right).

**SAMPLE 0127: Neg. 157-11: Tremolitized marble.** Shows remnant of original fine-grained ankeritic carbonate at bottom right, in contact with invasive phase of skeletal/bladed tremolite (bright colours) intergrown with coarser calcitic carbonate (tan colours).

**SAMPLE 0067: Neg. 157-6: Altered marble.** Shows part of pocket of fibrous, aggregate-textured serpentine (blue grey-black; right) in contact with coarse-grained mosaic aggregate of carbonate (brownish to pale pastel colours) with elongate flakes of muscovite (green, orange, blue-violet). Note minor pockets of serpentine in the carbonate near the contact, and occasional tiny flecks of carbonate in the main serpentine area.