DOLMAGE CAMPBELL & ASSOCIATES LTD.
CONSULTING GEOLOGICAL & MINING ENGINEERS
1000 GUINNESS TOWER
VANCOUVER 1, B.C.

British Columbia Hydro and Power Authority

PETROGRAPHIC AND GEOLOGIC FEATURES OF OXIDIZED (BURNT) ROCKS

Hat Creek Coal Deposits

November 10, 1977

Douglas D. Campbell

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

DOLMAGE CAMPBELL & ASSOCIATES LTD.
CONSULTING GEOLOGICAL & MINING ENGINEERS
1000 GUINNESS TOWER
VANCOUVER 1, B.C.

INTRODUCTION

Trenches dug in 1959 on the south and west side of the Dry Lake depression at the north end of the No. 1 Coal Deposit at Hat Creek exposed single pieces and clusters of pieces of hard, red-purple vesicular rock in the regolith. Core holes drilled in the same vicinity and southward during 1974-76 intersected similar material in what appeared to be the regolith, along with considerable quantities of red-to-yellow coloured, hard and soft shale and siltstones. From this evidence Dolmage Campbell suggested in their summary report on the geology of No. 1 Deposit summitted in June 1977 that the possibility of the existence of at least two areas of burnt in situ coal measures on the west side of the deposit should be considered. These areas were designated on a map (Fig. 10) accompanying that report as Burnt Zones.

In the summer of 1977 the excavation of Trench A on the west side of the deposit exposed extensive thicknesses of orange-yellow-red-brown coloured strata of the Coldwater Formation overlying the western extension of the No. 1 Deposit coal. Several extensive nests of hard vesicular rocks were also exposed lying on top of the coloured strata but beneath the overlying glacial till. This exposure suggested that burnt coal measures may be more extensive than earlier anticipated, in which case the possibility that relatively large quantities of coal may have been burned from the deposit had to be considered.

Follow-up investigation of this feature of No. 1 Deposit has consisted of a review of the surficial and core-hole geology that might contribute pertinent data and a petrographic (microscope) examination of 45 thin sections cut from 43 specimens of vesicular, baked and "burnt" material collected mostly from No. 1 Deposit, but also from the vicinity of No. 2 Deposit. The surface petrographic specimens of this material from both deposits were collected by Mr. J.F. McIntyre and the core specimens were selected during relogging of No. 1 Deposit holes by Messrs. L.T. Jory, J.F. McIntyre, P.J. Street and D.D. Campbell. In addition, Dr. Jory obtained three reference specimens of baked shale from Colorado and two reference specimens of coal-fire "clinker" from Wyoming.

The present report includes the results of the above-described geological and petrographic investigations and, in its appendix, the detailed petrographic analyses for each of the 45 thin sections examined by the writer. The evidence derived from petrographic microscopy of any one slide can be conclusive or inconclusive or even misleading, particularly in the case of rock origins or metamorphic processes. For this reason, if

petrological validity is to be established it is necessary to examine as many different specimens as possible under the microscope and to have a good knowledge of the geological setting from which the specimens have been selected. For the present study this prerequisite has been reasonably satisfied; however, the results have not been totally definitive since there remain some petrographic and geologic features that are somewhat ambiguous. Nevertheless, enough evidence has been accumulated to establish the general character and extent of the so-called "burnt material" in the No. 1 Deposit. The present report is a collection of data that can be used by geologists working at Hat Creek as background reference when new exposures of this type of material are revealed in the future.

This report is divided into five main sections: the first is a general discussion on the characteristics of coal-burnt rock; the second is a review of the pertinent geology of the Upper Hat Creek Valley and the No. 1 Deposit; the third is a summary discussion of the results of the petrographic examinations; the fourth is a discussion of the conclusions that can be derived from the geological and petrographic data; and the fifth and final section is the Appendix which includes 45 individual petrographic analyses.

BURNT COAL MEASURES

References in the literature on the petrography of burnt coal measures are sparse. One that has been used in the present study, "Baked Shale and Slag Formed by the Burning of Coal Beds", G.S. Rogers, U.S.G.S. Prof. Paper 108A, was written in 1917 and although it is not well enough documented to comprise a definitive reference, it does provide useful descriptions of some products of coal burning.

Burnt shales in B.C.

The writer has had extensive experience in drilling, mapping and studying the two most extensive known areas of burnt coal measures in British Columbia, one along the Peace River Canyon downstream of the Portage Mountain Dam, and the other on the east side of the Fraser River south of Quesnel. The first area is the largest and occurs within folded Cretaceous shale, siltstone and coal strata at a point on the river that was investigated first for the site of a dam. The relatively large and highly irregularly shaped underground voids left by the combustion of extensive coal seams and adjacent carbonaceous shales rendered the site unsuitable as a damsite. The second area, near Quesnel, occurs within flat-lying Tertiary coal measures essentially identical in character to the Coldwater coal measures at Hat Creek. Both the Peace River and Quesnel areas of burned strata extend over areas in excess of a square mile.

Both at Peace River, where the coal is till burning approximately 3000 feet downdip of the (canyon wall) outcrop, and at Quesnel, there are no obvious products from the combustion of the coal except voids. At Peace River, because of the inherent strength of the strata above the voids, there has been little or no collapse and surface subsidence; however, at Quesnel, because the voids are relatively shallow and flat, the overlying (weak) rocks have collapsed over very wide areas, forming unstable, slide-prone terrain.

The most striking feature of the burnt coal areas at both Peace River and Quesnel is the widespread occurrence of "baked shale" adjacent to the burnt (or burning) coal. This rock is characteristically relatively hard (5-6) and uniformly brick red-orange in colour. Under the microscope it is a hematite-impregnated mass of fine grains interspersed with elongate voids along the bedding. At Peace River, these voids appear to be the sites of incinerated bitumen material that is a common component of the shales. At Quesnel, the voids appear to be due to the generation and expansion of steam from the clay shale during the intial stages of baking. This characteristic of the Quesnel "burnt shale" renders it a marketable possolanic additive for cement and/or a light weight aggregate. At Peace River, the shales were not only baked by burning coal seams but were also far more extensively baked by combustion of their own bitumen compo-

nents which were ignited by the hot gases from the burning coal.

Products of coal combustion

Rogers, in his 1917 paper, describes the occurrence in the Western States of "vesicular glassy slag" near the sites of burnt out coal seams. He interprets this to be a product of hot gases, (350°C), escaping from the coal fire and fusing adjacent rock to a molten state that subsequently hardens into a vesicular glass. Specimens of similar material were obtained by Dr. Jory from Wyoming for this study. It is this material that has been compared with the vesicular rocks found at Hat Creek, thus introducing the possibility of the Hat Creek occurrence could have been formed by fusion from coal-fired hot gases.

The distinguishing characteristics of this slag-like material, which has been suggested as the product of fusion of adjacent rock and/or coal mineral matter, are: (1) a frothy appearance due to the high content (50% or more) of rounded vesicles, (2) a glassy, grayish matrix to the vesicles and, (3) reddened fragments of sedimentary rock encompassed by the frothy glass. Rogers reports that this fused product is most commonly vesicular glass, with "minor facies" of recrystallized minerals where depth of burial has been sufficient to permit slow cooling. He reports that the recrystallized minerals are confined to the "chimneys of slag", that the crystals are "fine" and that the minerals are generally metamorphic. The reported minerals are: magnetite, cordierite, epidote and plagioclase.

The "baked shale" occurring in the vicinity of burnt coal beds is evidently universally pink, red or purplish red in colour, occasionally mottled, and commonly has a splintery fracture resembling jasper. The red colour is due to the formation of hematite which tends to impregnate the rock, producing a relatively hard cement.

GEOLOGICAL SETTING

There are four principal locations in the valley of Upper Hat Creek where brightly coloured, oxidized Coldwater strata occur on the surface, with or without vesicular, fused rock. These areas, shown on Figure 1 of this report, are located as follows:

Area (1): 8000 feet west of the north end of No. 1 Deposit.
Area (2): northeast corner of No. 1 Deposit.
Area (3): 5000 feet east of the north end of No. 2 Deposit.
Area (4): at the south end of No. 2 Deposit.

Area #2 is the only one that is underlain by near-surface coal. The other three areas are immediately underlain by barren Coldwater sedimentary rocks or by Miocene volcanic rocks; therefore, it is most unlikely that their origins can be attributed to burning coal.

Area #1 is prominent bluff outcrop of brick red to maroon-brown coloured breccia in the form of pillars similar to those at Dry Lake. The rock consists of angular fragments of volcanic rocks in a matrix of vesicular basaltic material.

Area #2 includes the areas of Dry Lake and southwest of Dry Lake ("A" Trench), where exposures occur of brightly coloured (yellow-red-tan) Coldwater strata as well as abundant pieces in the regolith of breccias which consist of brick red, orange and buff coloured fragments of shaly rock in a vesicular gray or maroon coloured matrix. Specimens of breccia have been exposed on the surface and in the 1959 trenches around Dry Lake, as well as in drill holes near A Trench and in that trench. All of these occurrences are in the regolith above glaciated bedrock and below glacial till, where it exists.

Area #3 is a broad hill near the main road east of No. 2 Coal Deposit, in an area underlain by Miocene volcanic rocks, and consists of exposures of multicoloured volcanic breccias that include fragments of Coldwater sedimentary rocks and volcanic rocks in a basaltic matrix.

Area #4 is similar to Area 3 but also includes lahar-type volcano-mudflow rocks.

In the 1959 trenches, which are now filled, in the vicinity of Dry Lake many pieces of the vesicular "fused" material were exposed in soil, sand and gravels above bedrock. These pieces comprised the only hard rock in the regolith and showed evidence of discolouring the soil etc. around them. They are rounded in shape and were interpreted by the writer at that time as being volcanic bombs.

In Trench A, excavated in 1977 on the west side of No. 1 Deposit,

there are extensive exposures of yellow, tan and reddish coloured Coldwater strata, (Plate 1). These rocks are primarily soft shales and siltstones which include harder bands of relatively poorly defined, maroon coloured rock that appears to be baked shale, (Plate 3). Of interest in this exposure is the occurrence on the surface of these red coloured rocks on the south side of the trench, beneath glacial till, of clusters of pieces of the vesicular breccia. Also of interest in the Trench A exposures is the extensive occurrence at the west end of the trench of clearly weathered, oxidized coal lying directly beneath glacial till, (Plate 2). This oxidized coal, together with the soft nature of the Coldwater shales and siltstones in the same area, indicates that, unlike other parts of No. 1 Deposit, this part represents a relict of pre-Pleistocene tropical-type weathering of the Coldwater strata. Exposures very similar to lateritic tropically weathered profiles are common on both sides of Trench A, with leached hematite-limonite boxworks lying above earthy manganese-rich bands that cross all bedrock structures, (Plate 4).

PLATE 1

North wall of Trench A. Folded Coldwater strata.
Most of this rock is soft. The true colours are more yellow and pink than shown in photo.

PLATE 2

North wall of west end of Trench A. Coal.
Note the clearly oxidized zone (brown) cutting across the coal layers under the till. This indicates pre-glacial weathering, not burning.

PLATE 3

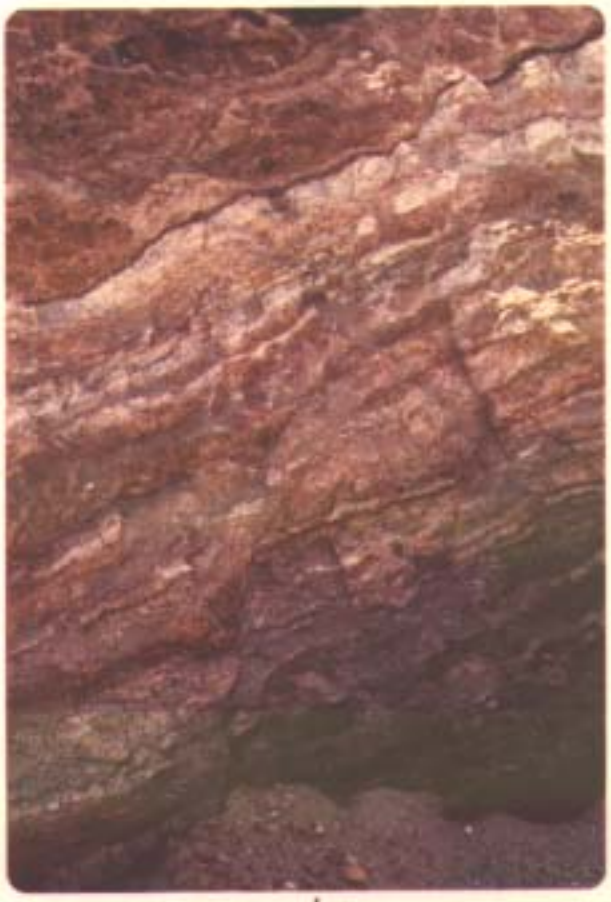
South wall of Trench A, near east end.

Soft, cream coloured Coldwater strata that include a wavey, diffuse band of harder, maroon coloured material, (arching from the bottom centre of the photo up to the right hand corner.), that is possibly "baked".

Interestingly, this occurrence is overlain by a "nest" of vesicular (tephra-like) rocks that is covered by till.

Also, there is no coal within or immediately beneath these coloured strata.

PLATE 4



South wall of Trench A, west of Plate 3.

Contact of coaly beds with overlying multi-coloured, soft, oxidized strata.

Note the thin, sharp black band near the top of the photo that crosses the small fault but is not displaced by it. This is a pyrolusitic band, similar to those commonly found in lateritic soil profiles beneath leached boxworks.

Note also the chaotic mass of ferruginous material above this pyrolusitic band, similar to the upper levels of a lateritic soil profile.

PETROGRAPHIC EXAMINATIONS

Of the 43 specimens studied in thin sections for this report, five of them (#1244-1248) were obtained by Dr. Jory from Colorado and Wyoming, with no detailed reference locations, and five (#963-965, 965A, 966) were collected by J.F. McIntyre in the areas of oxidized material located east No. 2 Deposit, (Figure 1). All of the rest of the specimens have come from drill holes and surface exposures in the northwest corner of No. 1 Deposit. The specific locations of these specimens are shown on Figure 2 of this report.

For ease of study, the 45 petrographic analyses prepared from the above specimens, (two extra slides were made for two of the specimens), have been grouped into three categories and are so presented in the Appendix. These are:

Group 1 - Vesicular material, (Variously termed slag, clinker, scoria and tephra by different geologists.).

- Slide numbers #1244, 1245	Wyoming specimens.
969	Surface, No. 1 Deposit.
970	Surface, No. 1 Deposit.
971	Surface, No. 1 Deposit.
972	Surface, No. 1 Deposit.
#1107-08	Drill cores, No. 1 Deposit.
1154-55	Drill cores, No. 1 Deposit.
1163-65	Drill cores, No. 1 Deposit.
1233-34	Drill cores, No. 1 Deposit.
1243	Drill cores, No. 1 Deposit.

Group 2 - Baked shale

- Slide numbers #1246-48	Colorado specimens.
963-964,965A	Surface, E. of No. 2 Deposit.
1109	Drill cores, No. 1 Deposit.
1156	Drill cores, No. 1 Deposit.
1162	Drill cores, No. 1 Deposit.
1239	Drill cores, No. 1 Deposit.

Group 3 - Oxidized (weathered) shale etc.

- Slide numbers # 914- 916	Drill cores, No. 1 Deposit.
965- 966	Drill cores, No. 1 Deposit.
1110	Drill cores, No. 1 Deposit.
1118-1122	Drill cores, No. 1 Deposit.
1160-1161	Drill cores, No. 1 Deposit.
1235-1236	Drill cores, No. 1 Deposit.
1240-1241	Drill cores, No. 1 Deposit.

The separation of these specimens into the above three categories is a natural one that required no interpretive judgements. If the specimen

exhibited "frothy" vesicular rock, it was included in Group 1. If it was a relatively hard, uniform brick red or orange coloured shale or siltstone, it was categorized as Group 2. (Specimens of baked shale fragments in a vesicular matrix were included in Group 1). If the specimen was relatively soft, sedimentary and of any colour, it was categorized as Group 3.

Details of the microscopic features of each specimen can be read in the individual petrographic analyses that are appended to this report. The remainder of this section (Petrographic Examinations) of the report is devoted to general discussion of the salient features of each type of rock studied in thin section. The discussions are under the same headings as the groups described above.

VESICULAR MATERIAL

Since we have no knowledge of the origin of the two specimens of slag-like material from the Powder River Basin in Wyoming, they are accepted as clinker products of burnt coal. One (1244) is entirely frothy vesicular glass; the other (1245) is a mixture of vesicular glass and red fragments of baked shale. Under the microscope, both of these specimens exhibit 50-70 percent voids in the vesicular material. These voids contain no mineral fillings and the surrounding groundmass is a cloudy glass with traces of an acicular, microcrystalline mineral that could be feldspar.

In contrast to the simple mineralogy of the Wyoming specimens, all of the specimens from Hat Creek exhibit a wide range of mineralogical complexity. In particular, a large number of the Hat Creek specimens exhibit, both megascopically and microscopically, partial and/or complete fillings of vesicles by comb-crystalline zeolites and plagioclase, a common characteristic of vesicular volcanic rocks.

The vesicular "slag" that forms the groundmass between the vesicles in the Hat Creek specimens ranges in texture from glass to fine crystalline. The compositions of the crystalline groundmasses studied are all clearly in the basaltic range, with the feldspar being largely basic plagioclase (bytownite-labradorite) and the (minor) mafic minerals including augite, magnetite, and hornblende (?). Of critical interest in many of the Hat Creek specimens is the abundant occurrence in the "slag" groundmass of relatively coarse, (up to 1 mm) corroded crystals of oligoclase plagioclase. The presence of these relict phenocrysts in a basaltic material clearly indicates to the writer a magmatic origin for the "slag" at a site of an earlier crystallization of material of more intermediate composition.

There is a complete absence in the Hat Creek vesicular rock specimens of the metamorphic minerals noted by Rogers (1917) in his examination of "coal slag" rocks.

Both the field and petrographic evidence suggest a strong likelihood that the specimens of vesicular "slag" or "clinker" found at Hat Creek are products of volcanic action rather than of the burning of in situ coal.

BAKED SHALE

The best petrographic criteria for the baked shale is found in the fragments of red shale that have been caught up in molten magma or slag in the previously discussed vesicular specimens. In these fragments the shale is a hard rock of predominantly hematite cement with up to 50 percent voids. The voids are generally elongate elliptical openings formed along the original lamination or scattered throughout the massive portions of the rock. They exhibit mineral fillings and evidently represent the "degassing" of the clay shales and siltstones through the generation of steam during heating. In several specimens of the baked shale in the vesicular melt, the recrystallization of the shale fragments has begun and signs of assimilation by the melt are clear. This is found only in those specimens exhibiting relatively coarsely crystalline basaltic groundmass.

The early stages of baking are marked by pervasive replacement of the clay groundmass by finely disseminated hematite; also, many individual silt grains are replaced by hematite. There is no significant amount of limonite in these rocks. The final stages of baked shale are characterized by a total conversion to hard hematite, with or without voids.

There is no megascopic or microscopic method of determining whether the baking of the shales was brought about by volcanic heat or coal-fire heat.

OXIDIZED (WEATHERED) SHALE

Specimens of yellow, red and brown shale have been collected from drill cores throughout the west side of No. 1 Coal Deposit, including from the A Trench. All of the specimens dealt with in this group in this study are characteristically soft and crumbly. Under the microscope they reveal a common development of laminar ragged voids and the pervasive development of limonite. Traces of pyrolusite and gypsum occur in some specimens. Hematite is locally developed but is not pervasive. The laminar voids have clearly developed at the expense of the clay groundmass of the primary shale. There is no indication of recrystallization, of the development of rounded (degassing) voids or of an impregnation by hematite cement, all of which are characteristics of the baked shale. Rather, all of the characteristics of the specimens of soft, oxidized shale are identical to those developed in weathered rock in warm climatic conditions.

DOLMAGE CAMPBELL & ASSOCIATES LTD.
CONSULTING GEOLOGICAL & MINING ENGINEERS
1000 GUINNESS TOWER
VANCOUVER 1, B.C.

CONCLUSIONS

In the writer's opinion, there is unambiguous in situ and petrographic evidence at Hat Creek to indicate the following:

(1) Some of the Coldwater shales etc. in the valley have been baked by volcanic action and some by undetermined actions, which could include in situ coal fire.

(2) Most of the specimens of vesicular slag found around No. 1 Deposit include fragments of baked shale and the "slag" portion of them is basaltic in composition and magmatic in texture.

(3) All of the vesicular slag specimens found to date occur above the glaciated(?) surface of unweathered bedrock, underneath glacial till, in the regolith in sections of drill holes that returned less than 20 percent core recovery, (Inset, Fig. 2).

(4) Most of the brightly coloured strata in Trench A are weathered material and are spatially associated with weathered, not burnt surface coal.

The above evidence leads the writer to conclude the following possible origins for the observed phenomena:

(1) The vesicular rock is volcanic in origin and was probably derived from explosive pipes. It was scattered as hot airborne coarse tephra (bombs) on the unglaciated surface of the Coldwater strata. Possibly this semimolten material ignited local, in situ coal and/or coaly beds, but this was a minor phenomenum at No. 1 Deposit.

One other possibility, suggested by the remnants elsewhere in the valley of Miocene volcanic breccias which include fragments of Coldwater strata, is that the specimens of baked shale etc. represent the remnants of the coaly Coldwater surface immediately beneath the contact of Miocene flows which covered part or all of the valley.

(2) The soft multicoloured strata in the vicinity of Trench A represent an erosional remnant of preglcial, tropically(?) weathered Coldwater rocks, including coal. These rocks are

similar in every respect to weathered Tertiary rocks in the Southwest states and would correspond to many other pockets of similarly preglacially weathered rocks scattered across southern British Columbia.

(3) There is no clear evidence of significant quantities of coal having been burnt in situ from the No. 1 Deposit at Hat Creek.

Respectfully submitted,

DOLMAGE CAMPBELL & ASSOCIATES (1975) LTD.

Douglas D. Campbell

APPENDIX

GROUP 1

VESICULAR ROCK
("Slag, clinker, scoria, glass and tephra")

#1244-45	Wyoming
#969-972	Surface, No. 1 Coal Deposit, Hat Creek
#1107-08 1154-55 1163-65 1233-34 1243	Drill cores, No. 1 Coal Deposit, Hat Creek

HAT CREEK PROJECT

PETROGRAPHY

Spec.No. 1244

ROCK CATEGORY: Clinker
Field Name: Coal-fire clinker Proper Name: SLAG
Location: Wasatch Fm., Powder River Basin, Wyoming

MEGASCOPIC DESCRIPTION:

Massive, hard (6-7), aphanitic, streaky, medium rose-grey, lightweight burn product that has solidified to include 50 percent unconnected gas bubbles that range in size from microscopic to 1 cm.

MICROSCOPY

GENERAL DESCRIPTION:

Approximately 40-50 percent of the slide is comprised of circular (gas bubble) voids in a fine grained (0.15 mm) to microcrystalline brownish grey matrix which includes clear fragments (0.15-0.02 mm) of quartz. Most of the matrix is comprised of fine, long (0.1 mm) needle-like crystals that have about 30° extinction.

The composition of the matrix components is hindered by the cloudy colouring, but glass may be present.

MINERALS

%		
50	Voids	Sharply defined, generally circular and separate bubbles.
7	Quartz	Angular fragments and splinters (0.15-0.02 mm) of clear quartz scattered randomly throughout matrix.
30	Unknown	Relatively high relief, clear to slightly greenish, needle-like crystals in acicular and star-shaped clusters. Too fine and clouded to readily identify. May be zeolite (matrolite) (scolecite?)
13	Unknown	Possible divitrified glass et al in cloudy, fine crystalline matrix.

DISCUSSION

The presence of bubble voids indicates that the material had reached a plastic state and that water vapour etc. had been driven from the original material (rock?) by heating. The residual quartz fragments suggest a possible sedimentary origin (shale?).

HAT CREEK PROJECT

PETROGRAPHY

Spec.No. 1245

ROCK CATEGORY: Clinker
Field Name: Coal-fire clinker
Location: As #1244

Proper Name: - CLINKER (SLAG)

MEGASCOPIC DESCRIPTION:

Massive, multicoloured (purple-brick red), aphanitic, hard (5-6), moderately lightweight slag type product with about 30 percent of the purple matrix made up of unconnected bubbles, but no bubbles in the brick-red fragments (1"-3"). Red fragments are reactive to HCl.

MICROSCOPY

GENERAL DESCRIPTION:

Much like #1244 only with higher proportion of voids (60-75%) and much darker, (cloudier) matrix and with no quartz fragments.

Contrary to megascopic appearance, the red fragments have equally as many voids as the purple groundmass, but they tend to be smaller. Under the microscope the other difference between the red fragments and purple groundmass is that the matrix of the purple rock is a mass of fine acicular needle-like crystals like in #1244, (albite?), in a black matrix.

MINERALS

%

Mineral identification of the cloudy submiscrscopic matrix between the voids is not readily possible optically. Judging from the relative weight of the specimen despite 60-75 percent voids, plus the red-purple colour, it is inferred that much of the material must be oxides of iron.

The source of the HCl reactivity is not obvious.

DISCUSSION

The material has been heated to a plastic state (bubbles) and the original composition destroyed. The fineness of grain suggests rapid cooling.

HAT CREEK PROJECT

PETROGRAPHY

Spec. No. 969

ROCK CATEGORY: Burn
Field name: Scoria Proper name: TEPHRA
Location: Surface, south side of Dry Lake. No. 1 Deposit.

MEGASCOPIC DESCRIPTION: Honeycomb mass of splintery plate-like cream and pink, foliated rock fragments (up to several centimeters in length), cemented in a dark purple, iron-rich, "frothed" groundmass that is 60 percent cavities (bubbles), lightweight.

Hard (5) to soft (3).

MICROSCOPY

GENERAL DESCRIPTION: The entire slide is made up of porous, contorted and flattened, wafer-like masses of largely opaque material, but with minor inclusions of clusters of quartz and cloudy feldspar fragments and crystals (0.2-0.5 mm).

The voids in the opaque wafers are mostly elongate partings; however, clusters of round "froth" air bubbles are common and are associated with the non-opaque mineral clusters that include subhedral quartz, feldspar and possibly cristobalite.

MINERALS

%		
65	Opaque mineraloids	Fine-grained, locally banded and contorted rock mass whose character is masked by an isotropic mineraloid that is white to cream coloured in reflected light, but black to dark brown in transmitted light. Most of the splintery, broken and twisted rock fragments are pale tan to yellowy orange in colour and contain 25 percent elongate voids. The more solid-appearing, "frothy" masses are deep red or maroon in thin section and contain about 25 percent voids, but they are spherical.
25	Voids	Elongate "expanded bedding planes (?)" in the light coloured rock fragments. Spheroidal "bubbles" in the dark "melt" material.

MINERALS

%		
7	Cavity filling	Many of the elongate cavities, particularly the narrower ones (0.1-0.5 mm), are wholly or partially filled with cloudy-clear masses of a microcrystalline (0.01-0.04 mm), generally low birefringent mineral which appears to be chloritic clay accompanied by (lesser) red hematite grains.
3	Igneous minerals	Clusters of relatively coarse (0.5-1.0 mm) subhedral crystals of quartz, plagioclase and cristobalite (?) occur close to and within the "frothy" melt material that tends to coat and join the platey rock fragments. Also occurring in these sites are clusters of intergrown microcrystalline (0.03 mm) enhedral elongate crystals of twinned plagioclase, typical of the quenched plagioclase found in volcanic melts. The larger quartz and feldspar crystals that occur in the "frothy" masses are all fractured and variously brecciated and the feldspars (plagioclase) are commonly very cloudy and corroded. Also, in the "frothy" mass are two clouded fragments (1 mm) of light coloured, fine crystalline lithic material, possibly volcanic.

THIN SECTIONS 969A and 969B: Two extra thin sections were made from this specimen in order to provide the opportunity to study the rock in different dimensions. The general characteristics of the rock are the same in these sections as those described above for No. 969; however, particular features of interest in them are as follows:

969A: Approximately 50 percent of the frothy "magmatic" rock that forms the cement for the flattened burnt shale wafers in this section is made up of relatively coarse (0.5 mm) cloudy and cracked crystals and fragments of quartz, plagioclase (oligoclase) and other nonidentifiable minerals (heavily clouded). Noteworthy in the magmatic melt or froth is one fragment, 4 mm in length, of aphanitic intermediate volcanic rock.

Also the magmatic melt in this section contains abundant, clear, relatively coarse crystaline (0.1-0.2 mm) radiating clusters of quenched basaltic plagioclase (bytownite) together with sheaves of clouded hornblende.

969B: The most noteworthy features in this section are the relatively excellent and abundant examples of radiating clusters of quenched basaltic plagioclase and the striking fact that wafers of baked (hematized and dried) shale are essentially unaltered or recyrstallized even though they are encased in a vesicular mass of basaltic-like melt.

DISCUSSION

The platey, contorted fragments that make up most of this rock are baked and "expanded" shale that has been picked up by the darker, frothy "magma" which contains broken crystals of quartz, soda plagioclase and hornblende as well as igneous lithic fragments and cluster of quenched basic plagioclase, typical of basaltic glasses.

It is difficult to conceive how the above igneous minerals and rocks could have been formed in a melt from burning coal, especially since the grain size in the adjoining baked shale fragments has not changed from its original.

The most logical origin for this rock is that it is a piece of volcanic tephra formed by molten basaltic froth erupted from a vent. The contorted, baked shale fragments have been picked up from the vent walls and the whole mass has been ejected and landed as a piece of scoria or bomb (tephra) on the Pleistocene ground surface.

HAT CREEK PROJECT

PETROGRAPHY

Spec. No. 970

ROCK CATEGORY: Burn
Field name: Scoria
Proper name: BAKED RECRYSTALLIZED SHALE (TEPHRA?)
Location: Surface, south side of Dry Lake. No. 1 Deposit

MEGASCOPIC DESCRIPTION: Dull brick red, moderately hard (5-6), curving thinly laminated, aphanitic rock intricately interleaved with voids both as spaces between laminae and as fine bubbles in the rock. Relatively heavy considering the high void ratio (50-60%). Some laminae are paper--thin.

MICROSCOPY (Two thin sections)

GENERAL DESCRIPTION:

Section 970A: All but a very minor area of this slide is made up of red, baked fine-grained shale that includes a myriad of elongate, "flattened" voids. The shale is fine-grained and unrecrystallized; however, it has been rendered opaque in thin section by the impregnation with hematite from the oxidation of its iron.

Of major interest on this slide is that one corner of it is made up of dark grey melt-like rock with spheroidal vesicles. This rock has a gradational contact with the baked shale, whose voids are flat. This suggests the possibility, although the evidence is not entirely conclusive on this slide, that the shale has been heated high enough, at least locally, to render it soft enough (plastic?) to permit the gas voids to assume a spheroidal shape.

Section 970B: This section is essentially the same in general character as No. 970A; however, most of it is made up of reddish grey and grey rocks (with the more spheroidal-shaped voids) that is evidently gradational from the baked shale. In this example the rock is clearly uniformly recrystallized (0.05-0.25 mm) to a cloudy assemblage of equidimensional-subhedral clay-feldspar, sheaves of incipient plagioclase and minor clusters of quartz. Also, fine acicular crystals of plagioclase have grown into some of the voids, indicating that recrystallization began after gas (steam?) from the heated shale had formed the voids.

DISCUSSION

This example of baked shale that appears to be gradational into a recrystallized rock suggests the possibility of the shale being the source for at least some molten or plastic slag. However, this specimen was picked up from the surface in an area of considerable tephra, therefore it could have been recrystallized in a volcanic vent or perhaps by burning coal in situ.

HAT CREEK PROJECT

PETROGRAPHY

Spec. No. 971

ROCK CATEGORY: Burn
Field name: Scoria Proper name: TEPHRA
Location: Surface, south side Dry Lake. No. 1 Deposit

MEGASCOPIC DESCRIPTION: A rubbly porous breccia of baked shale in a vesicular "melt". The laminated fragments of shale in the purple "froth" (vesicular) are uniformly brick red and are more or less identical to No. 970. Relatively lightweight. The fragments are moderately hard (5-6) and the glossy froth is hard (7).

MICROSCOPY

GENERAL DESCRIPTION: Most of the slide is made up of red-brown fragmented baked shale that is impregnated with hematite and laced with "bedding plane voids" but is otherwise not altered (i.e.) not recrystallized. The shale fragments are all rimmed by a dark grey, vesicular, aphanitic (melt) rock that only locally exhibits slightly gradational contacts, which, here, suggest digestion by a molten (magma) material rather than by recrystallization.

The magmatic interstitial rock is locally heavily clouded with hematite but is uniformly composed of finely crystallized (0.05 m) basaltic plagioclase (bytownite) with some relict (corroded) bytownite phenocrysts (1.0 mm).

DISCUSSION

This slide clearly indicates that the "magma" material that has picked up the baked shale fragments originated as a basaltic magma from a volcanic vent, hence the vesicular froth. The corroded bytownite phenocrysts indicate transport of the magma from depth before it passed through Coldwater (presumably) shales.

This slide suggests that the recrystallized shale in No. 970 probably originated in the volcanic vent, since the melt is definitely basaltic in origin and not a melted shale from a coal fire. (Such material could not form coarsely crystalline basic plagioclase within the pressure-time conditions of near-surface coal fires.)

HAT CREEK PROJECT

PETROGRAPHY

Spec. No. 972

ROCK CATEGORY: Burn
Field name: Scoria Proper name: TEPHRA
Location: No. 1 Deposit. Surface, Dry Lake.

MEGASCOPIC DESCRIPTION: Identical to No. 970.

MICROSCOPY

GENERAL DESCRIPTION: The majority of this slide is made up of fine-grained to microcrystalline opaque material that is almost completely hematized and is full of elongate, flattened voids (40%). Throughout the hematite mass are dispersions of a cloudy, fine crystalline, high birefringent, needle to platey mineral that may be sericite, (recrystallized clay?).

Also, of most interest on this slide is a cluster of very cloudy, corroded, subhedral, poorly twinned plagioclase (intermediate-basic) crystals that are partially hematized. These crystals appear more to be relicts from an early phase of the evolution of this rock, rather than the products of (new) recrystallization.

DISCUSSION

This rock is made up primarily of baked and degassified shale fragments that appear to be somewhat recrystallized. The presence of apparently relict basic plagioclase feldspar crystals on the edge of a baked shale wafer suggests an origin for the rock from the side of a volcanic plug or vent, rather than as a product of melting from buring coal.

HAT CREEK PROJECT

PETROGRAPHY

Spec. No. 1107

ROCK CATEGORY: Burn
Field name: Clinker Proper name: TEPHRA (Vesicular basalt)
Location: No. 1 Deposit, DH 76-182, 146-151' (80% core loss)

MEGASCOPIC DESCRIPTION: Hard (6), massive, "agglomerate"-type of rock comprising light coloured (tan, cream and white), angular to subround rock fragments, (1 mm - 2 cm), in a dark grey vesicular (frothy) matrix. The vesicles comprise about 15-20 percent of the rock and range up to 4 mm in diameter. The rock fragments appear to be baked and degassed shales, sandstones, and possibly igneous.

MICROSCOPY

GENERAL DESCRIPTION: A cryptocrystalline grey-brownish-clear groundmass that encompasses a wide variety of foreign rock fragments (40%) and vesicular air pockets (25%). The air pockets are round to subround and several are partially filled with comb-structured silicate minerals. Fragments (0.5 mm) of cloudy, somewhat corroded plagioclase crystals are common in the groundmass.

About 20 percent of the slide is made up of curved, wafer-like fragments of rusty coloured shale that are variously host to air pockets and are generally surrounded by dark reaction rims. Some exhibit extensive growth of fine crystalline feldspar-zeolite (?) crystals within a cryptocrystalline groundmass. Many of them are a solid mass of brown limonite (hematite?) in the centre with rims of cloudy-clear, comb-crystalline (0.10 mm), nascent plagioclase (oligoclase?).

COMPOSITION: The groundmass is composed predominantly of feathery, subhedral, cloudy and locally corroded oligoclase crystals. Anhedral fragments of quartz are an ubiquitous but relatively minor component. Cloudy, pale green, anhedral-subhedral augite grains (0.05-0.02 mm) are common. Relatively large (0.5 mm), highly corroded, or poorly formed, subhedral crystals of basic plagioclase, (labradorite), are common, as are rounded ghost fragments of aphanitic basaltic rock.

Relatively fresh, euhedral columnar crystals of muscovite and hornblende are relatively common both in the groundmass and even in some of the recrystallized shale fragments.

Hornblende is common throughout the groundmass, as well as comb infilling in many of the vesicles.

DISCUSSION

The predominant rock is a VESICULAR BASALT that includes corroded phenocrysts of basic plagioclase and partially ingested (recrystallized) fragments of aphanitic basalt. Fragments of (Coldwater?) shale have been picked up by the molten basaltic magma and have been baked, distorted, degassed and considerably recrystallized.

HAT CREEK PROJECT

PETROGRAPHY

Spec. No. 1108

ROCK CATEGORY: Burn
Field name: Clinker Proper name: TEPHRA (Vesicular basalt)
Location: No. 1 Deposit, DH 70-182, 156-161' (80% core loss)

MEGASCOPIC DESCRIPTION: Essentially identical to No. 1107 only several pieces are dirty, subrounded (eroded?) and weathered, suggesting surface transport and/or extended time of exposure on the surface as a detrital product. Nonreactive.

MICROSCOPY

GENERAL DESCRIPTION: Generally the same as Specimen 1107 except the slide includes a greater content of hematized partially digested (recrystallized) fragments of shale.

Also, the groundmass contains a very high percentage of needle-like crystals (0.05-0.10 mm) of quenched plagioclase (?)

Mafic minerals are much more sparse than in No. 1107.

DISCUSSION

Like Specimen 1107, this rock is a VESICULAR BASALT that includes corroded basic plagioclase phenocrysts, and abundant fragments of baked and variously recrystallized shale.

The rock is approximately 50 percent round to subround, unlined vesicles (0.5 - 5-10 mm).

HAT CREEK PROJECT

PETROGRAPHY

Spec. No. 1154

ROCK CATEGORY: Burn
Field name: Clinker Proper name: TEPHRA (Vesicular basalt)
Location: No. 1 Deposit, DH 76-167, 248' (80% core loss)

MEGASCOPIC DESCRIPTION: Identical rock to No. 1107-1108 in DH 767-182 400 feet north. Pale coloured shaley rock fragments in dark grey vesicular matrix.

MISCROSCOPY

GENERAL DESCRIPTION: The slide comprises two large (1-2 cm) subround fragments of cloudy-opaque "baked" shale in a highly vesicular (50%) matrix of fine (0.05-0.5 mm) crystalline, clear feldspar-mafic-magnetite igneous rock.

Approximately 60 percent of the slide is made up of baked shale fragments, some of the smaller ones of which are invaded by tongues and porphyroblasts of feldspar. The shale fragments are densely clouded by mineraloids (leucoxene and hematite), so mineral identification is not possible by microscope. However, it is clear that the shale is only incipiently recrystallized, although locally invaded by feldspar from the surrounding matrix. The basaltic matrix has been chilled at the contact with the fragments.

MINERALS - (Matrix only)

5/70	Anorthite	The plagioclase is generally clear and well twinned, and it occurs in two habits; (1) as stubby, small (0.1-0.02 mm) subhedral crystals, often cloudy, and (2) as long (0.1-0.5 mm) columnar crystals which tend to be slightly corroded around their peripheries. Includes minor chilled needles. The large crystals are not uncommonly in rosettes.
15	Magnetite	Fine crystalline (0.02-0.10 mm) euhedral grains and clusters of grains of magnetite are interstial to the anorthite throughout this rock. Includes some cloudy limonite (?).
10	Glass	Brownish grey, low relief, isotropic interstitial filling. Commonly with magnetite.

MINERALS - (Matrix only)

%		
5	Augite	Irregularly distributed, high relief, brownish green, non-pleochroic subhedral crystals generally interstitial to the plagioclase.

DISCUSSION

The matrix within which the shale fragments occur is a normal, locally glassy vesicular BASALT. The petrographic evidence indicates that the shale fragments have been eroded and invaded by the basaltic melt in a "stoping" action, rather than assimilation by recrystallization.

It would appear that the rock was derived when molten basalt, either in a vent or in the base of a now-eroded flow, picked up fragments of shale prior to final solidification.

HAT CREEK PROJECT

PETROGRAPHY

Spec. No. 1155

ROCK CATEGORY: Burn
Field name: Clinker Proper name: TEPHRA (Basalt)
Location: No. 1 Deposit, DH 76-167, 257' (90% core loss)

MEGASCOPIC DESCRIPTION: As No. 1154 only practically entirely composed of dark grey to black, hard, vesicular matrix with ghost outlines of absorbed (?) rock fragments.

MICROSCOPY

GENERAL DESCRIPTION: This rock is essentially the same as Specimen 1154 except the baked shale fragments are smaller and the slide includes one rounded "pebble" fragment (5 mm) of sandstone whose quartz grains are unaltered but whose clay (?) matrix has been hematized.

The basaltic matrix is generally finer crystalline than that in No. 1154, much of it being cloudy cryptocrystalline. Of interest in this matrix are a number of relatively large (1-2 mm), cloudy corroded phenocrysts of oligoclase that have evidently been transported in the basaltic melt from an earlier, deeper site of crystallization.

All of the shale fragments are rendered opaque by hematite and possibly leucoxene and all have been impregnated by fine, incipient crystals of plagioclase. In addition, up to 50 percent of each fragment is made up of voids. In contrast to No. 1154, where the basalt around the shale fragments is chilled, the rimming basalt in this specimen is commonly more coarsely crystalline than the body of the matrix.

DISCUSSION

The rock is essentially the same as No. 1154, but the evidence here, in the oligoclase phenocrysts, for a definite magmatic source is clear. The presence of a fragment of sandstone, with the shale, suggests a mixing of rocks during transport. The rock is a VESICULAR BASALT with baked foreign fragments.

HAT CREEK PROJECT

PETROGRAPHY

Spec. No. 1163

ROCK CATEGORY: Coldwater (Burn?)
Field name: Tuff (?) Proper name: VOLCANIC GLASS (Tuff)
Location: No. 1 Deposit, DH 76-191, 120'. As #1160.

MEGASCOPIC DESCRIPTION: Uniform, massive, somewhat lightweight, compact, hard (6), pale cream with tan hue, very fine-grained with scattered, small (0.5 mm) irregular-shaped voids. Non-reactive.

MICROSCOPY

GENERAL DESCRIPTION: Fine-grained (0.3-0.05 mm), opaque brown-black and cloudy-clear mosaic of largely isotropic to low birefringent grains in sub-round shapes. All cut by network of microscopic fractures that have the appearance of dessication cracks.

MINERALS

%		
3	Quartz-feldspar	Clear, subround, low-birefringent grains and clusters, generally 0.10 mm and less. Many of these could be zeolites.
10	Opaques	Both limonite grains (large) and angular fragments of magnetite and schorlite (tourmaline).
2	Voids	Various irregular-shaped voids, some of which are wholly or partially filled with zeolite.
85	Groundmass (Glass?)	Fine-grained, irregularly brown (limonite-clay?) clouded, generally isotropic mineral or mineraloid. Probably altered volcanic glass.

DISCUSSION

The lack of definite structure, fabric or grains, together with the total isotropic nature of most of this slide, suggest that the rock is VOLCANIC GLASS.

HAT CREEK PROJECT

PETROGRAPHY

Spec. No. 1164

ROCK CATEGORY: Coldwater (Burn)
Field name: Clinker Proper name: GLASS
Location: No. 1 Deposit. DH 76-191, 136'. As #1160

MEGASCOPIC DESCRIPTION: Irregularly banded (2 mm - 1 cm), black, grey and cream coloured, hard (7), compact, lightweight expanded shale type of rock. About half of the rock is made up of voids (0.5-1.0 mm) that are elongate and flat in the cream-grey bands, but round in the black (frothy) bands.

MICROSCOPY

GENERAL DESCRIPTION: The entire slide is composed of black, opaque material encompassing flattened, irregular shaped empty voids (0.1-4.0 mm).

The opaque matrix is dull grey-white under reflected light.

MINERALS

%		
50	Glass (?)	Opaque frothy matrix. The different coloured bands in the hand specimen are included in the thin section but are virtually indistinguishable mineralogically.
50	Voids	Evidently relicts of degassification.

DISCUSSION

This rock would appear petrologically to be a volcanic GLASS; however, the distinct layering, colour banding and irregular, flattened voids suggest possibly a plasticized shale that has been reduced to glass.

HAT CREEK PROJECT

PETROGRAPHY

Spec. No. 1165

ROCK CATEGORY: Coldwater (Burn)
Field name: Burned sandstone Proper name: CRYSTALLINE TUFF(?)
Location: No. 1 Deposit. DH 76-191, 145'. As #1160, (Near fresh coal surface).

MEGASCOPIC DESCRIPTION: Crudely wavey banded, hard (6-7), competent, medium-pale grey, silty grained rock completely impregnated with fine, (0.1-0.5 mm), irregularly shaped voids. Includes irregular patches of diffuse brick red colour flanking fractures. Non-reactive.

MICROSCOPY

GENERAL DESCRIPTION: Uniform crystalline aggregate of brown-black opaque patches (25%), angular fragments (15%) of fractured, clear feldspar and minor quartz, cloudy rosettes of plagioclase microlites (20%) and irregular-shaped, unconnected, locally partially filled voids (40%).

MINERALS

%		
15	Feldspar fragments	Low relief, low birefringent, angular, fractured fragments (0.10-0.20 mm) of K-Na feldspar. Minor quartz, if any.
20	Plagioclase microlites	Fine granular to rosette microlites (0.1 mm) of clear, rudely twinned platioclase (oligoclase?), generally encompassed in and partially clouded by the opaque mineraloid.
25	Opaque mineraloid	Fuzzy, opaque patches (0.10-0.20 mm) clouding the microlite and microcrystalline interstitial filling between the feldspar grains etc. Probably mostly limonite.
40	Voids	Clearly defined, unconnected voids that are essentially the same size and shape as the feldspar grains. Generally angular and mostly within the matrix.

DISCUSSION

This rock appears to be a tuff; however, it could also possibly be a baked silty shale that has been degassed and whose clay groundmass has been converted to a limonite-plagioclase microlitic mosaic. The latter interpretation of origin requires considerable extrapolation of the evidence. Since the first interpretation is less contrived, it is the most likely one, namely; a CRYSTALLINE TUFF.

HAT CREEK PROJECT

PETROGRAPHY

Spec. No. 1233

ROCK CATEGORY: Burn
Field name: Clinker Proper name: TEPHRA (vesicular glassy basalt)
Location: No. 1 Deposit, DH 77-216, 18'. (A-Trench)

MEGASCOPIC DESCRIPTION: Identical to No. 1108, 1107 and 1154, only matrix is more vesicular and included shale fragments are larger and more full of voids (degassified).

MICROSCOPY

GENERAL DESCRIPTION: The slide consists of two fragments of baked shale, that comprise 60% of the slide, in a highly vesicular (40%) crystalline-glassy matrix. The vesicles in the matrix are bulbuous in shape and relatively large (0.25-2.00 mm) whereas those in the shale fragments tend to be smaller (0.05-1.00 mm) and elongate in shape, being oriented along microfractures. The voids in the shale fragments comprise about 30 percent of the rock.

The shale fragments are largely clouded with opaque hematite; however, about 5 percent of the fragments is magnetite, in fine (0.02 mm) crystals scattered throughout the rock, and at least 30 percent is made up of equally fine (0.01-0.02 mm) grains (microcrystals) of feldspar(?).

The vesicular matrix is made up of rounded, often clustered-like grapes, voids (40%) within a clear to cloudy crystalline groundmass whose composition is given below.

MINERALS (Matrix)

%		
40	Voids	Described above. Some are lined with a rim of fine crystalline magnetite and needles of (quenched?) plagioclase project into many of them.
15	Oligoclase	Clusters of stubby, subhedral crystals that are slightly cloudy, poorly twinned, strained and commonly overgrown with needles of quenched plagioclase. Crystal size is generally uniform (0.05-0.1 mm).

MINERALS (Matrix) (cont.)

%		
15	Anorthite	Cloudy-clear, relatively large (0.25-0.5 mm), skeletal subhedral crystals that appear to be corroded relicts of an earlier crystallization.
10	Magnetite	Clusters and bands of microcrystalline (0.01 mm) euhedral fresh crystals. Frequently rimming vesicles.
20	Microcrystalline minerals	Often cloudy, densely packed. Includes long needles of chilled plagioclase (?), devitrified glass and other, minor unidentified minerals.

DISCUSSION

As in previous specimens of vesicular rock studied in this suite, this rock is compositionally a BASALT. It's relict feldspar phenocrysts, chilled feldspar needles, and mixed crystal fabric strongly suggest an igneous origin, (VESICULAR BASALT), rather than a coal fire melt.

HAT CREEK PROJECT

PETROGRAPHY

Spec. No. 1234

ROCK CATEGORY: Burn
Field name: Clinker (volcanic ash?) Proper name: OBSIDIAN
Location: No. 1 Deposit, DH 77-216, 26'. (A-Trench)

MEGASCOPIC DESCRIPTION: Large core of massive, uniform, hard (6-7), dark maroon-grey, aphanitic, faintly (pale grey) porphyritic, finely vesicular basalt (?). Very similar to the matrix of No. 1107, 1108, 1154 and 1233.

MICROSCOPY

GENERAL DESCRIPTION: Uniform, cloudy, semi-opaque submicroscopic-grained mat of (possibly) devitrified glass. Approximately 50 percent of the rock is occupied by subround to angular (microfracture-controlled) vesicles about 30 percent of which are partially or entirely filled with comb-crystalline, cloudy-clear zeolite.

MINERALS

%		
45	Voids	Round to angular vesicles, some of which trend along, or are joined by, microfractures. This suggests late concentration of gas after the rock (glass?) had begun to solidify.
20	Zeolite	Partial or complete, cloudy-clear vesicle filling. Probably chabazite.
3	Magnetite	Discontinuous microscopic threads in groundmass.
2	Biotite	Frequent alteration (brown) of zeolite.
30	Groundmass	Submicroscopic, near-opaque, largely isotropic mass. Probably devitrified glass.

DISCUSSION

This rock is a devitrified vesicular OBSIDIAN.

HAT CREEK PROJECT

PETROGRAPHY

Spec. No. 1243

ROCK CATEGORY: Burn
Field name: White tuff (?) Proper name: VOLCANIC GLASS
Location: No. 1 Deposit, DH 77-216, 13'. (A-Trench)

MEGASCOPIC DESCRIPTION: Massive, white, moderately hard (4), aphanitic rock. Scattered, irregular-shaped voids.

MICROSCOPY

GENERAL DESCRIPTION: Completely uniform, dark cloudy grey, near-opaque, massive vesicular devitrified glass, (isotropic).

About 15-20 percent of the rock is occupied by round to subround vesicles (0.05-0.10 mm).

About 10-15 percent of the rock is very finely crystalline magnetite.

About 15-20 percent of the rock is composed of weakly developed, cloudy zeolite that partially fills some vesicles and is distributed throughout the groundmass.

DISCUSSION

The rock is a vesicular VOLCANIC GLASS.

APPENDIX

GROUP 2

BAKED SHALE

#1246-48	Colorado specimens
# 963	Surface, east of No. 2 Coal Deposit, Hat Creek
964	
965A	
#1109	Drill cores, No. 1 Coal Deposit, Hat Creek
1156	
1162	
1239	

HAT CREEK PROJECT

PETROGRAPHY

Spec.No. 1246

ROCK CATEGORY: Baked shale
Field Name: Baked shale (Mesaverde Grp). Proper Name: - BAKED SHALE
Location: Colowys Mine, N.W. Colorado

MEGASCOPIC DESCRIPTION:

Massive, uniform pale (brick) orange, soft (4), very fine grained, normal weight shale.

MICROSCOPY

GENERAL DESCRIPTION:

Very fine grained (0.01 mm), faintly banded shale that has an orangy brown overall colour that is imparted by the fact that about 30 percent of the grains are red-orange (limonite-hematite?). About 30-40 percent of the rock is composed of clear, colourless quartz. Scattered shell fragments of calcite are common in the shale as are streaks and partings that were probably coal or carbonaceous material but that are now hematite.

MINERALS:

%		
40	Quartz	Fine (0.01 mm), subangular grains forming clear, colourless part of slide.
40	Hematite(?)	Irregularly shaped, very fine grains of low-relief brownish-orange mineral that appears to be hematite. Possibly oxidized mica, other ferromagnesian mineral grains and/or clay. Also in bands and knots of previous carbonaceous (coal?) material.
19	Sericite-clay	Very fine (0.01-0.005 mm) needles and grains forming remainder of groundmass.
1	Calcite	Scattered fragments of small (0.25-1.00 mm) shells lying along bedding.

DISCUSSION

The rock is a typical detrital (quartz)-clay shale that has evidently been rendered red coloured by the oxidation of about 30-40 percent of its mineral grains. Such oxidation would appear to have been from heat because weathering would not oxidize the carbonaceous material.

HAT CREEK PROJECT

PETROGRAPHY

Spec.No. 1247

ROCK CATEGORY: Baked shale
Field Name: Baked shale (Mesaverde Grp.) Proper Name: - BAKED SHALE
Location: As #1246 (Colo.)

MEGASCOPIC DESCRIPTION:

Massive to crenulate-fissile, uniform maroon brick red, soft (4), very fine grained, normal weight shale with scattered nodules (mud balls) up to 7 mm in diameter giving rougher surfaces than #1246.

MICROSCOPY

GENERAL DESCRIPTION:

The slide is comprised entirely of uniform, fine grained, opaque hematite (reflected light) with scattered cuspate voids of relict fossils (shells?).

MINERALS:

%	
Hematite	This opaque, red-orange material totally masks the character of the mineral mass.

DISCUSSION

Apparently the original shale (fossiliferous) has been baked, as pottery clay is fired, to form an opaque impregnation of hematite "glaze".

HAT CREEK PROJECT

PETROGRAPHY

Spec.No. 1248

ROCK CATEGORY: Baked sandstone
Field Name: Baked sandstone Proper Name: Arkosic sandstone
Location: Colowyo Mine, N.W. Colorado

MEGASCOPIC DESCRIPTION:

Small specimen of massive to faintly banded, moderately hard (5), very fine grained (silty), normal weight, very pale brownish red, silty sandstone.

MICROSCOPY

GENERAL DESCRIPTION

Relatively fine grained (0.01-0.10 mm) arkosic sandstone comprising generally angular grains of quartz (60%) with lesser feldspar? mica, calcite, ferromagnesian minerals and carbonaceous (?) material.

The reddish colour of the rock is due to the reddish oxidation of the ferromag minerals and the carbonaceous material.

MINERALS

%		
60	Quartz	Clear, angular grains and fragments that are somewhat commonly oriented, but are not appreciably sorted. None have been tinged (coloured) by oxidation.
15	Micas	Pale brown flakes distributed throughout. Brown colour is non-pleochroic and masks normal pleochroism; therefore, is oxidation.
20	Ferromagnesian Minerals	Relatively high relief, irregularly sized and shaped, pale brown to reddish sub-opaque grains. Obviously oxidized.
5	Calcite etc.	Scattered, relatively large, high relief unoxidized (clear) grains.

DISCUSSION

This sandstone is a relatively common detrital type of rock whose pale reddish tint could have been imparted by "baking", or by weathering.

HAT CREEK PROJECT

PETROGRAPHY

Spec.No. 963

ROCK CATEGORY: Oxidized
Field Name: Ash(?) Proper Name: Shale (Possibly baked)
Location: No. 2 Deposit area (E?). Surface.

MEGASCOPIC DESCRIPTION:
Small chips of deep reddish black, soft (3), fissile, easily broken shale (?).

MICROSCOPY

GENERAL DESCRIPTION:
Uniform, fine crystalline (0.03-0.05 mm), dense aggregate of stubby, flakey, subhedral, rectangular grains. Well banded by brown clouding alternating with clear bands (0.05-0.15 mm). Approximately 15 percent of the grains are opaque stubby rectangular hematite that are evidently oxidized magnetite.

MINERALS

%		
80	Clay	Flakey, subhedral, low relief, low birefringent grains that form the mass of the rock. Some of this is somewhat high birefringence and is therefore probably sericite.
15	Hematite	Opague, red, euhedral crystals that impart the reddish hue to the rock. Evidently oxidized ferromags and magnetite of the original shale.
5	Quartz etc.	Evenly distributed anhedral grains of quartz, feldspar and other minor detrital minerals.

DISCUSSION

This rock is a clay SHALE that has possibly been slightly baked, since the original iron-rich minerals have been oxidized to hematite and the clay has been somewhat crystallized. The softness of the rock, however, suggests oxidation by weathering rather than by baking.

HAT CREEK PROJECT

PETROGRAPHY

Spec.No. 964

ROCK CATEGORY: Oxidized
Field Name: Baked shale Proper Name: Oxidized Shale
Location: Surface sample probably NE of No. 2 Deposit.

MEGASCOPIC DESCRIPTION:
Massive, very fine grained, uniform brick-orange, fairly hard(4-5).

MICROSCOPY

GENERAL DESCRIPTION:
Evenly colour banded (0.2-2.0 mm), brown and clear, relatively coarse grained (0.02-0.07 mm) shale made up of clear angular detrital mineral grains, hematite grains and red-brown clouded groundmass grains. Slide has 10-15 percent grain sized voids.

MINERALS:

%		
50	Clay	Ultrafine, crystalline felted masses and clouded flakes making up groundmass of rock. Many clear and cloudy detrital "grains" are made up entirely of micro-crystalline clay.
20	Quartz et al	Subround to angular detrital grains, generally clear. Also includes some feldspar, mica etc.
15	Hematite	Fuzzy clots and grains of red hematite (reflecting light) as well as dust that impregnates and clouds the rock mass.
15	Voids	Grain sized and shaped voids. Probably plucked during slide preparation.

DISCUSSION

This rock is an OXIDIZED SHALE in that the relative abundance of hematite and the pervasive orange colour are sharply aberrant from the Coldwater unweathered shales.

HAT CREEK PROJECT

PETROGRAPHY

Spec. No. 965A

ROCK CATEGORY: Burn (?)
Field name: Ash Proper name: SHALE
Location: Probably NE of No. 2 Deposit. Surface.

MEGASCOPIC DESCRIPTION: Medium brown-grey, massive, soft (3-4) slightly fissile shale. Very similar to No. 963, but the latter has been possibly baked to give it a reddish tinge and a slightly harder surface.

MICROSCOPY

GENERAL DESCRIPTION: Essentially the same shale as Specimen 965 except for (1) more, continuous and wider (0.12 mm) clear and relatively clear bedding bands (25% of rock), (2) pale-to-dark brown colours, (rather than the yellows and reds of 965), and (3) a relatively high content (10%) of evenly distributed, fine (0.2-0.05 mm) columnar, opaque crystals.

The colour changes from clear to brown is diffuse under high magnification.

MINERALS:

%		
80	Clays	Dense mass of ultrafine grained amorphous and acicular to columnar grains. Exhibits range two types of birefringence, one very low and the other considerably higher, suggesting a possible mixture of montmorillonite and kaolinite types.
10	Quartz et al	Scattered, relatively large, rounded to angular, clear grains and fragments. Probably includes feldspars and other minerals as well as the predominant quartz.
10	Hematite	All of the opaque crystals are deep red hematite.

DISCUSSION

This rock is a clay SHALE that has been only very slightly oxidized, as evidenced by the alteration of the fine columnar mineral to opaque hematite.

HAT CREEK PROJECT

PETROGRAPHY

Spe. No. 1109

ROCK CATEGORY: Burn
Field name: Clinker Proper name: BAKED SHALE
Location: No. 1 Deposit, DH 76-182, 116-171', (80% core loss)

MEGASCOPIC DESCRIPTION: Dull brick red powder and crinkled rock flakes of hard (5) and soft (3), baked and moderately degassed shale (?). Nonreactive.

MICROSCOPY

GENERAL DESCRIPTION: This slide is made up entirely of one piece of finely laminated (0.5-0.05 mm), locally highly contorted, very fine grained shale. The rock is colour banded brown to red to yellow-grey to opaque by limonite-hematite and a fine crystalline, white (opaque) mineraloid (leucoxene?).

The clay (?) mass of the shale shows incipient recrystallization by coalesence along the bedding planes, but not by the formation of spicules of feldspar such as occur in the vesicular basalt tephra specimens.

DISCUSSION

This slide is a "BAKED" SHALE. The baking in this specimen is evidenced by hematization, deformation and by incipient recrystallization and degassing.

HAT CREEK PROJECT

PETROGRAPHY

Spec. No. 1156

ROCK CATEGORY: Burn
Field Name: Baked shale Proper name: OXIDIZED (BAKED) SHALE
Location: No. 1 Deposit, DH 76-167, 290'. (Base of regolith that had 10% recovery).

MEGASCOPIC DESCRIPTION: Somewhat lightweight, massive, pale orangey brick colour, relatively hard (5-6), very fine grained, baked (?), silty shale. Impregnated with pinpoint voids.

MICROSCOPY

GENERAL DESCRIPTION: This slide is made up entirely of massive, unsorted, angular to subround feldspar grains (0.1-0.01 mm) and minor quartz and magnetite grains. The finer grained groundmass of this rock is entirely impregnated with dull red-brown hematite (dust). Also, about 5 percent of the primary grains have been pseudomorphically replaced by bright red hematite.

The relative hardness and compact character of this rock has been imparted by the impregnation, and resulting cementation, by hematite. Presumably, the hematite groundmass represents a total replacement of the original clay minerals that originally formed the cementing matrix of the rock.

MINERALS

%		
17	Voids	Subround and angular, unconnected voids that are generally larger (0.1-0.25 mm) than the largest grains in the rock; nevertheless, many appear to be sites of leached-out grains.
20	Feldspar-quartz	Predominantly untwinned feldspar with minor twinned oligoclase and quartz. All of the feldspar is variously clouded by hematite and somewhat corroded. None appears to have been formed by recrystallization from the (clay) matrix during baking.
3	Magnetite	Opaque euhedral grains scattered through the rock. Some are variously altered to hematite.
60	Hematite	Both discrete grains and the dull impregnation of the groundmass.

DISCUSSION

The rock is an OXIDIZED SILTY SHALE. The oxidation has been accompanied by a hardening of the rock through the conversion of clay(?) etc. to a hematite matrix, indicating probable baking, rather than weathering.

HAT CREEK PROJECT

PETROGRAPHY

Spec. No. 1162

ROCK CATEGORY: Coldwater (Burn?)
Field name: Burnt shale Proper name: BAKED SILTY SHALE
Location: No. 1 Deposit, DH 76-191, 116'. As #1160.

MEGASCOPIC DESCRIPTION: Uniform, pale orange, relatively hard (4), compact, fine-grained shaley rock with somewhat conchoidal fracture. Non-reactive.

MICROSCOPY

GENERAL DESCRIPTION: Uniform skeletal, microscopic three dimensional lacework of hematite-limonite embracing a residue of unbedded, unsorted round to subangular grains (0.03-0.15 mm) of clear to cloudy feldspar, quartz and minor hematite.

MINERALS

%		
25	Detrital grains	Mostly quartz and feldspars (rarely twinned), variously clouded with limonite. Some may be zeolites.
75	Hematite - Limonite	Skeletal lacework that embraces the relict detrital minerals in the rock.

DISCUSSION

The hardness and compact competence of this rock is imparted principally by the fine, pervasive hematite-limonite lacey framework that has pseudomorphically replaced most of the original (clay?) groundmass of the rock, which was probably a SILTY SHALE. Since weathering processes tend to decompose and soften a rock, the hardening and cementing by hematite-limonite of this specimen suggest that it was imparted by some other process, probably baking. Thus, this rock is probably a BAKED SILTY SHALE.

HAT CREEK PROJECT

PETROGRAPHY

Spec. No. 1239

ROCK CATEGORY: Burn
Field name: Baked Shale
Location: No. 1 Deposit, DH 77-215, 22'
Proper name: BAKED SHALE (A-Trench)

MEGASCOPIC DESCRIPTION: Massive, heavy, hard (5), vaguely mottled dark brick red, very fine-grained, dense (minor voids), baked (?) shale.

MICROSCOPY

GENERAL DESCRIPTION: This slide is made up of a uniform, structureless dense opaque red mass of hematite that is impregnated with euhedral grains (0.10-0.05 mm) of magnetite, much of which is partially converted to hematite. Each magnetite grain is surrounded by a haloe of clear, amorphous silicate (?).

MINERALS

%		
1	Feldspar	Scattered relict angular grains, (0.10 mm).
15	Magnetite	Euhedral, generally skeletal grains separately scattered throughout the rock.
10	Silicate	Amorphous to microcrystalline, clear haloes around the magnetite grains. Probably feldspar-clay relict of original clay (?) groundmass that is revealed as a result of a "reaction rim" around the magnetite in a field of hematite.
74	Hematite	Amorphous, opaque groundmass.

DISCUSSION

This rock is an intensely BAKED SHALE with the only recrystallization probably being the magnetite.

APPENDIX

GROUP 3

OXIDIZED (WEATHERED) SHALE
(Includes some unweathered shale)

# 914-916	Drill cores, No. 1 Coal Deposit, Hat Creek
965-966	
1110	
1118-1122	
1160-1161	
1235-1236	
1240-1241	

HAT CREEK PROJECT

PETROGRAPHY

Spec. No. 914

ROCK CATEGORY: Oxidized Coldwater
Field name: Burnt shale Proper name: WEATHERED SILTSTONE
Location: No. 1 Deposit, DH 74-38, 111'. Red-orange and yellowish pieces of core in high core-loss (50%) section on top of solid shaley coal.

MEGASCOPIC DESCRIPTION: The rock is pale pinkish-tan, relatively hard (4), fine colour bedded and ultra-fine-grained with some coarser-grained layers. It is highly permeable, and non-calcareous. Bedding planes at both ends of the drill-core sample carry well-preserved impressions of deciduous leaves. Vesicular or solution type voids along bedding planes are common, although the specific gravity of the rock is essentially normal for a siltstone-shale.

MICROSCOPY:

GENERAL DESCRIPTION: Under the microscope this sample displays the texture of a sandy siltstone, with perceptible if poorly defined bedding expressed by contrasting grain-size. There is no strictly gradational sorting, and relative concentrations of coarser grains are set in a much finer matrix somewhat in the manner of a greywacke. Overall colour is pale brown, but the rock contains abundant angular colourless grains of feldspar and quartz, and appreciable disseminated very fine-grained carbonaceous material and opaque magnetite grains surrounded by hematite-limonite halves.

Under high magnification it appears that microcrystalline chlorite-clay comprise the very fine-grained groundmass.

MINERALS

%		
35	Feldspar-quartz	Angular to subangular fragments of crystals, from very fine to 0.25 mm. Mostly (biaxial), non-twinned feldspar, relatively fresh (unclouded), except for very fine grains that tend to be clouded with limonite and/or groundmass.
10	Magnetite	Angular to subangular grains in same size ranges as the feldspar-quartz grains. All are variously replaced by hematite and surrounded by pronounced limonite haloes.

MINERALS

%		
53	Chlorite - clay (?)	Ultrafine grained green (chlorite) and colourless, low relief, low birefringent grains that form the groundmass.
2	Pyrite	Euhedral to subhedral, variously hematized, corroded margin grains.

DISCUSSION

This rock is a SHALEY SILTSTONE that has been moderately oxidized, probably by weathering. The lack of recrystallization of the chlorite-clay and pervasive hematization suggest that combustion, or baking, did not affect this rock. The voids in the specimen are not evident in the slide; however, it is suggested that they are caused by leaching under normal weathering conditions.

HAT CREEK PROJECT

PETROGRAPHY

Spec. No. 915

ROCK CATEGORY: Oxidized Coldwater
Field name: Burnt shale Proper name: WEATHERED SHALE (?)
Location: No. 1 Deposit, DH 74-38, 123'

MEGASCOPIC DESCRIPTION: Brick red and reddish cream powdery "soil" and solid core of pale orange-creamy buff, gritty to very fine grained, poorly sorted, vaguely banded, poorly cemented, very soft (1-2), clayey rock. Breaks down readily in water. Highly porous. Non-calcareous.

MICROSCOPY

GENERAL DESCRIPTION: A loosely banded, disintegrated (intricately fractured) generally platey or flakey mass of dessicated limonite and limonitized minerals.

Because of the near-ubiquitous cover of iron oxide, positive identification of primary minerals is not possible under the microscope; however, the less densely oxidized areas reveal a fine-grained, scaley texture suggestive of either original clay mineralogy and/or breakdown by alteration (weathering) to limonitic clay products.

DISCUSSION

The crude banding and texture of the specimen indicate a probable sedimentary origin. The disintegration of the rock into a soil-like form, together with intense limonitization, suggest alteration by weathering processes. In Canada such advanced oxidation weathering indicates a pre-Pleistocene product that escaped removal by glaciation. Such pockets of residually weathered rocks are found throughout the southern fringe of B.C., generally only east of the Coast Range, as in parts of the Okanagan Valley, the Columbia River Valley (Revelstoke damsite) and in the Kootenays (Ymir).

It is a lateritic type of weathered product.

HAT CREEK PROJECT

PETROGRAPHY

Spec. No. 916

ROCK CATEGORY: Oxidized Coldwater
Field name: Burnt shale Proper name: WEATHERED SHALE (?)
Location: No. 1 Deposit, DH 74-38, footage unknown (74-148).

MEGASCOPIC DESCRIPTION: Deep brick red, almost maroon, massive, soft (2), very fine-grained, reworked porous clay or mud that has hardened upon drying. Much of it has crumbled to hematitic grit. A few fragments of cream-coloured shale occur in the red matrix.

MICROSCOPY

GENERAL DESCRIPTION: The section is comprised entirely of brecciated (dessication cracks) masses of opaque brown to pale tan (clouded) amorphous mineraloids. About 30-40 percent of the slide is opaque hematite, much of which occurs as subround spherulites (0.05-.10 mm) that probably originated as pyrite or siderite.

The non-hematite mineraloid material is cloudy (grey), low relief, low birefringent, submicroscopic scaley mat that appears under high magnification to be predominantly a mixed chlorite-clay layer mineral. Very fine (submicro) subhedral crystals of carbonate (?) are locally scattered throughout this groundmass. In some places in the groundmass ghosts of possible relict or incipient feldspar (?) crystals are suggested by patches of higher birefringence.

MINERALS

%		
40	Hematite	Amorphous, opaque masses and spherulitic (colloidial?) grains distributed erratically throughout the groundmass.
60	Clay - chlorite(?)	Submicroscopic grained, scaley mass of low birefringent mineraloid that appears, under high magnification, to be composed of incipient chlorite microcrystals in a clay-type matrix.

DISCUSSION

This material is essentially identical in mineral content and texture to LATERITIC SOIL, similar to that formed from Tertiary rocks in the Southwest U.S., etc. It probably represents relict pre-glacial regolith (weathered rock).

HAT CREEK PROJECT

PETROGRAPHY

Spec. No. 965

ROCK CATEGORY: Burn (?)
Field name: Ash Proper Name: OXIDIZED SHALE
Location: Surface sample, probably NE of No. 2 Deposit

MEGASCOPIC DESCRIPTION: Essentially identical to No. 964 only more yellow in colour on fresh surfaces. Fracture surfaces are unevenly reddish orange in colour, but this colour only penetrates beyond the fracture face for about 0.5 mm.

MICROSCOPY

GENERAL DESCRIPTION: Locally and discontinuously colour banded with thin (0.02 mm) colourless bands unevenly distributed on the general pale brown colour of the rock.

Relatively poorly sorted grains (0.01-0.12 mm), with relatively lesser number of grains larger than 0.04 mm. Most of the larger grains are clear, opaque ones are very minor. In the groundmass about 15 percent of the grains are reddish, 25 percent are clear and the remainder are yellow-brown.

Most of the large clear grains are quartz. The groundmass is a felted mass of clay, variously stained from yellow to brown-red by oxidized iron.

MINERALS

%		
95	Clay	Ultrafine, felted mass of flakey clay(s). The various shades of yellow, brown and red are evidently simply stages of discolouration by iron oxidation. Clear and oxidized grains are intimately intermixed. Low birefringence suggests a predominance of kaolins.
2	Quartz	Relatively coarse, angular to round, clear grains.
2	Hematite	Scattered large and small, dark red grains.
1	Opaque	Unidentified grains.

DISCUSSION

Like Specimen 965, this rock is an OXIDIZED SHALE. The pervasive nature of the rusty discoloration, together with its higher concentration along fractures, suggests that the oxidation could most probably be due to weathering.

HAT CREEK PROJECT

PETROGRAPHY

Spec. No. 966

ROCK CATEGORY: Burn (?)
Field name: Ash Proper name: SHALE
Location: Surface. Probably NE of No. 2 Deposit

MEGASCOPIC DESCRIPTION: Pale yellowish cream coloured, massive, soft (2), very lightweight, very fine-grained ash-type rock. Nonreactive.

MICROSCOPY

GENERAL DESCRIPTION: An essentially colourless, (very pale yellowish), and non-banded version of Specimen 965. A dense felted mass of ultra-fine grained (0.02 mm) clay mineral groundmass with scattered, coarser (0.1-0.2 mm) fragments and grains of quartz and micro fossiliferous fragments of what appear to be blades of grass, (0.25-1.0 mm). These microfossils are clear and only become noticeable under crossed nicols.

MINERALS

%		
95	Clay	Dense, clear, ultrafine grained (0.01-0.05 mm), bladed felted mass of extremely low birefingent mineral. Suggests montmorillonite.
5	Quartz et al:	Scattered, relatively large (0.05-0.1 mm) grains and fragments of quartz, limonite, hematite and the fossil flora, which appears to be mostly calcite.

DISCUSSION

This rock is a clay SHALE, not an ash. It has not been noticeable oxidized either by weathering or by burning.

HAT CREEK PROJECT

PETROGRAPHY

Spec. No. 1110

ROCK CATEGORY: Burn
Field name: Clinker Proper name: WEATHERED SHALE
Location: No. 1 Deposit, DH 76-182, 181-186' (80% core loss).

MEGASCOPIC DESCRIPTION: Very lightweight, soft (2), crumbly, flakey, clayey, cream and pink-brown, vaguely bedded ash or baked shales. Many pieces (the specimen ranges from powder to 4 cm pieces) are partially coated with sooty black pyrolusite (?), suggesting surface exposure (weathering).

MISCROSCOPY

GENERAL DESCRIPTION: The slide is made up of friable, sinuously laminated (0.4-2.0 mm), pale brown, uniformly submicroscopic grained (in faint laminations) hematized shale.

There is no evidence of recrystallization, degassification or other pyrometamorphic effects.

MINERALS

%		
40	Hematite	Sinuous bands (0.05-0.10 mm) of opaque very fine crystalline (specularite) material and amorphous dust.
48	Clay minerals(?)	Generally brown-yellow dusted, submicroscopic grained, platy fabric groundmass of the rock.
10	Voids	Discontinuous, thin (0.05-0.10 mm) lensey openings parallel to the laminae. Invariably rimmed by hematite concentrations.
2	Schorlite	Scattered clusters of fine (0.05 mm), slate blue enhedral crystals strung out along laminations. Evidently detrital.

DISCUSSION

This pink-cream-brown coloured rock shows no signs of being "baked", but with the pervasive development of hematite and development

of voids along the micro bedding planes, with concentration of hematite around the voids, together with the softening and breakdown of the rock, suggest that it is a WEATHERED SHALE.

HAT CREEK PROJECT

PETROGRAPHY

Spec. No. 1118

ROCK CATEGORY: Oxidized rock
Field name: Baked shale
Proper name: WEATHERED ARKOSIC SHALEY SILTSTONE

Location: No. 1 Deposit, DH 77-38, 65'.

MEGASCOPIC DESCRIPTION: Wavey, crinkly banded (with discontinuous cavities up to 1 mm in width), relatively hard (4-5), silty grained, uniform pale tan, non-reactive, relatively compact "baked shale". The planar cavities in the rock occur along bedding and fracture planes and appear to be more like leaching products than gas cavities. The rock is very porous.

MICROSCOPY

GENERAL DESCRIPTION: Crudely bedded, essentially unsorted assemblage of angular, clear to cloudy, frequently corroded, grains of feldspar (K-Na), quartz, magnetite and chloritized mafic minerals, in a cloudy, pale tan, microscopic grained clayey groundmass. The grain size of the detrital grains ranges from (0.05-0.2 mm).

The magnetite grains are largely altered to hematite and the surrounding minerals were stained by a limonite haloe.

The rock is interrupted by discontinuous, planar voids developed along the bedding, ranging in width from 0.05-2.0 mm, and comprising about 25 percent of the slide.

MINERALS

%		
30	Feldspar, quartz	Angular, unsorted fragments, about one-third to a half of which are probably quartz.
7	Hematite	Scattered grains of oxidized magnetite.
38	Clay groundmass	Submicroscopic, cloudy-clear structureless, almost isotropic, low-relief mass that seems to be composed of, under high magnification, fine nuclei of chlorite in a clay groundmass. Probably mixed chlorite-clay layer.

MINERALS

%		
25	Voids	Ubiquitous bedding cavities that are neither filled nor lined with any secondary minerals, as are the vesicular voids in the "melt" portion of the tephra-like rocks from the Dry Lake to the north.

DISCUSSION

This rock is a relatively mildly oxidized ARKOSIC SILTSTONE that has lost much of its cohesive strength by leaching of the cement through weathering.

HAT CREEK PROJECT

PETROGRAPHY

Spec. No. 1119

ROCK CATEGORY: Oxidized rock
Field name: Baked shale
Proper name: WEATHERED ARKOSIC SHALEY SILTSTONE

Location: No. 1 Deposit, DH 77-38, 75'

MEGASCOPIC DESCRIPTION: Uniform, massive, compact, relatively hard (4), very fine-grained, uniform pale tan (somewhat greyer than No. 1118), non-reactive "baked shale". There are occassional, small solution-like cavities in this rock similar to those in No. 1118. Porous rock.

MICROSCOPY

GENERAL DESCRIPTION: Essentially a finer grained version of No. 1118 only with a more cloudy groundmass, fewer large grains and less numerous, smaller voids. Also, it is faintly colour banded (bedded) although the grains are not sorted. The overall colour of the rock is more uniformly rusty, (limonitized).

MINERALS

%		
25	Feldspar, quartz	Angular, unsorted grains (0.02-0.10 mm); mostly feldspar.
20	Limonite - hematite	Red-brown grains entirely replaced by limonite and (minor) hematite. Also cloudy patches throughout groundmass.
10	Voids	Incipient, discontinuous (0.10 x 1.0 mm), bedding plane openings. Unlined and unfilled.
45	Mixed Clay	Submicroscopic, cloudy mass of chlorite (?) and clay. Probably mixed chlorite-clay mineraloid. No evidence of recrystallization or "baking".

DISCUSSION

This rock is similar to No. 1118 but more oxidized and somewhat finer grained. It is an oxidized ARKOSIC SHALEY SILTSTONE. Because the clay matrix is not recrystallized and the limonitization is grain-selective and the voids appear to be solution-type, it would appear that the oxidation and alteration of the rock is due to WEATHERING, rather than burning.

DISCUSSION

This rock is an arkosic SILTY SHALE that is unoxidized but has been subjected to moderate leaching, either by weathering (surface waters) or by groundwater.

HAT CREEK PROJECT

PETROGRAPHY

Spec. No. 1120

ROCK CATEGORY: Oxidized rock
Field anme: Baked silty sandstone Proper name: ARKOSIC SILTY SHALE

Location: No. 1 Deposit, DH 77-38, 85'.

MEGASCOPIC DESCRIPTION: Uniform, massive, very compact, relatively hard (4), pale greyish-cream, non-reactive, silty (fine) sandstone.

MICROSCOPY

GENERAL DESCRIPTION: Uniform, faintly bedded (colour bands), mottled clear and cloudy grey coloured rock composed of an aggregate of round to angular grains (0.03-0.10 mm) of clear feldspar and quartz in a sub-microscopic, cloudy-greenish matrix of chlorite-clay (?).

About 20 percent of the slide is made up of evenly distributed, unlined and unfilled voids that have the same sizes as the grains of the rock.

MINERALS

%		
60	Feldspar-quartz	Predominantly feldspar (K-Na) crystal fragments, mostly angular, but commonly rounded, ranging from clear to heavily clouded (argillized).
10	Opaques	Mostly somewhat fuzzily outlined carbonaceous (coaly?) material, with minor magnetite grains.
20	Chlorite - clay groundmass	Generally cloudy grey, low-relief, low birefringent unrecrystallized, submicroscopic grained cement between the grains that make up most of the rock.
20	Voids	Separated, evenly distributed voids of the general size of the rock grains, but more rounded in shape. They are ragged-edged and neither lined nor filled with secondary minerals. Many instances of voids surrounding isolated grains suggest that they have been formed by the differential leaching of the mixed chlorite-clay cement.

HAT CREEK PROJECT

PETROGRAPHY

Spec. No. 1121

ROCK CATEGORY: Oxidized rock
Field name: Baked shale
Proper name: WEATHERED SHALE (CLAYSTONE)

Location: No. 1 Deposit, DH 77-38, 106'.

MEGASCOPIC DESCRIPTION: Uniform, massive, very fine grained, soft (2), pale greyish cream, highly porous, non-reactive, somewhat remolded clay shale (mudstone). Checked around periphery by dessication cracks.

MICROSCOPY

GENERAL DESCRIPTION: Distorted, crudely banded, relatively coarse platey-grained (0.10-0.50 mm) fibrous-scaley mass of the greenish-grey and opaque brown, low relief, low birefringent, faintly pleochroic mixed clay-chlorite (?).

Subround to angular detrital grains (0.1-0.5 mm) of chlorite, hematite and limonite are common throughout.

MINERALS

%		
25	Hematite - limonite	Pseudomorphic replacements of detrital (?) grains and crystals as well as opaque impregnations of the mass.
25	Voids	Extensive cracks and fractures, many of which may have been opened by slide preparation, but most of which are natural.
50	Mixed Chlorite-clay	Scaley, amorphous greenish, faintly pleochroic, low birefringent mat.

DISCUSSION

This specimen appears to be an oxidized (weathered), non-recrystallized, leached, remolded CLAYSTONE. There is no evidence of "baking", but ample evidence of decomposition by weathering.

HAT CREEK PROJECT

PETROGRAPHY

Spec. No. 1122

ROCK CATEGORY: Oxidized rock.
Field name: Baked shale Proper name: WEATHERED SHALE (CLAYSTONE)

Location: No. 1 Deposit, DH 74-38, 127'.

MEGASCOPIC DESCRIPTION: Essentially identical to No. 1121 only coarser grained, sandstone, (gritty siltstone).

MICROSCOPY

GENERAL DESCRIPTION: Essentially identical to No. 1121 only more dense (minor voids) and a more uniformly textured and coloured, pale, faintly pleochroic tan, fibro-scaley mass of mixed clay-chlorite (?).

DISCUSSION

A remolded CLAYSTONE; weathered shale?

HAT CREEK PROJECT

PETROGRAPHY

Spec. No. 1160

ROCK CATEGORY: Coldwater (Burn?)
Field name: Tuff (?) Proper name: WEATHERED SHALE
Location: No. 1 Deposit, DH 76-191, 77'. Section of till and tephra (?) etc. on surface of fresh coal.

MEGASCOPIC DESCRIPTION: Core that has largely disintegrated to fine flakey chips and nodules; one large piece remains. Uniform, massive, soft (3), slightly fissile, very fine-grained to slightly silty, pale brownish tan coloured, weathered to dark brown on exposed surfaces. Non-reactive.

MICROSCOPY

GENERAL DESCRIPTION: The slide is made up of broken, interconnected, ragged-edged wafers of a clear to opaquely brown (limonite) clouded, fine-grained clay groundmass (0.01 mm) with scattered occasional sub-round cloudy grains (0.03-0.15 mm) of limonite, chlorite, quartz, feldspar, brown hornblende and zeolite (?).

MINERALS

%		
3	Primary Detritals	Quartz, feldspar and brown hornblende. All are generally corroded and partially limonitized.
70	Clay Minerals	Dense flakey fine-grained mat of low relief, pale greenish (?) brown, dusty, faintly pleochroic, low to slight birefringent minerals that appears to be a chlorite-clay (kaolin-illite) mixture.
2	Secondary Detritals	Pseudomorphic, flakey replacement of detrital grains by chlorite, limonite and zeolite (?)
20	Limonite	Opaque replacement or coating of all minerals. Occurs in diffuse patches and bands.

DISCUSSION

The rock is not recrystallized, hardened or impregnated with voids; therefore, it is not a baked product. It has no characteristics of a tuff. It is a moderately weathered (decomposed and limonitized) SHALE.

HAT CREEK PROJECT

PETROGRAPHY

Spec. No. 1161

ROCK CATEGORY: Coldwater (Burn?)
Field name: Tuff (?) Proper name: WEATHERED SHALE
Location: No. 1 Deposit, DH 76-191, 87'. As #1160.

MEGASCOPIC DESCRIPTION: Identical to #1160.

MICROSCOPY

GENERAL DESCRIPTION: Essentially the same as #1160 only with more clouding by dense, opaque limonite.

MINERALOGY: Same as #1160.

DISCUSSION

This rock and specimen #1160 were suspected, because of their pale tan colour, somewhat lightweight and rather compact character, of being tuffs (ash). Microscopic study reveals them to be limonitized (weathered) clay-shales.

HAT CREEK PROJECT

PETROGRAPHY

Spec. No. 1235

ROCK CATEGORY: Burn
Field name: Ash (?) Proper name: OXIDIZED (WEATHERED) SHALE
Location: No. 1 Deposit, DH 77-216, 62' (A-Trench)

MEGASCOPIC DESCRIPTION: Crumbly, pinkish pale cream coloured, massive, faintly bedded, soft (3), highly absorbent, fairly lightweight nonreactive (burnt?) claystone. Traces of fine amorphous iron and manganese oxide on fractures, suggesting surface weathering.

MICROSCOPY

GENERAL DESCRIPTION: Finely laminated (0.01-1.0 mm), grey-black-brown, very fine-grained (0.01-0.005 mm) rusty clay shale. Approximately 20 percent of the slide is made up of voids that have developed as discontinuous lensey partings along the foliation and as ragged breaks across it.

There are no silt-size grains in the slide, it is entirely shale in grain size.

Most of the rock is impregnated with pale to dark brown limonite and minor hematite, rendering it nearly opaque. The primary clay-feldspar (?) groundmass is just discernible through the iron mineraloid alteration.

MINERALS

%		
50	Clay	Micro-fibro-crystalline, cloudy mat of relatively high birefringent clays.
20	Voids	As described above. The voids look more like leaching cavities than gas-formed bubbles.
25	Limonite	Alteration and replacement of clay groundmass.
5	Hematite:	Accompanying limonite.

DISCUSSION

This rock is typical of OXIDIZED SHALE that is a product of weathering. There are no indications of baking or pyrometamorphism.

HAT CREEK PROJECT

PETROGRAPHY

Spec. No. 1236

ROCK CATEGORY: Burn
Field name: Clay Proper name: OXIDIZED (WEATHERED) SHALE
Location: No. 1 Deposit, DH 77-216, 74' (A-Trench)

MEGASCOPIC DESCRIPTION: Crumbly, greyish and pinkish cream coloured, soft (3), finely crinkly banded, remolded rusty (limonitized) clay. The periphery of the core is coated with a veneer of brick red hematite and the core is cut by crinkly layers of hematite.

MICROSCOPY

GENERAL DESCRIPTION: Essentially the same as No. 1235 only the decomposition and oxidation process has proceeded further, so that much more of the rock is openwork laminar cavities and the limonite is more intense (opaque brown).

In one part of the slide there is a cluster of cloudy-clear, subhedral crystals (0.05-0.10 mm) with moderate birefringence that appear to be secondary gypsum.

DISCUSSION

This rock is an intensely WEATHERED SHALE.

HAT CREEK PROJECT

PETROGRAPHY

Spec. No. 1240

ROCK CATEGORY: Burn
Field name: Baked shale Proper name: OXIDIZED SHALE
Location: No. 1 Deposit, DH 77-215, 30' (A-Trench).

MEGASCOPIC DESCRIPTION: Essentially identical to No. 1239 only cream coloured instead of red and softer (4). Fracture surfaces coated with black sooty pyrolusite (?) indicative of surface weathering.

MICROSCOPY

GENERAL DESCRIPTION: Uniform, dense, ultrafine grained (0.01 mm) mass of unsorted sedimentary grains with a few larger grains of feldspar fragments (0.05 mm). All except the larger grains are impregnated or stained by hematite, thus the slide is a red-brown colour.

There are no voids and no evidence of recrystallization. The oxidation (hematite-limonite) has attacked the groundmass (clay) first and has only begun to replace the silt-sized feldspar grains.

DISCUSSION

This is an OXIDIZED SHALE whose hematization is in its initial stages and could be due to either weathering or low grade baking.

HAT CREEK PROJECT

PETROGRAPHY

Spec. No. 1241

ROCK CATEGORY: Burn
Field name: Clay Proper name: WEATHERED CLAY SHALE
Location: No. 1 Deposit, DH 77-215, 50'. (A-Trench)

MEGASCOPIC DESCRIPTION: Fine flakey chips, (powder - 3 cm), soft (3), crinkley banded, brown and cream, oxidized (limonite) clayey rock.

MICROSCOPY

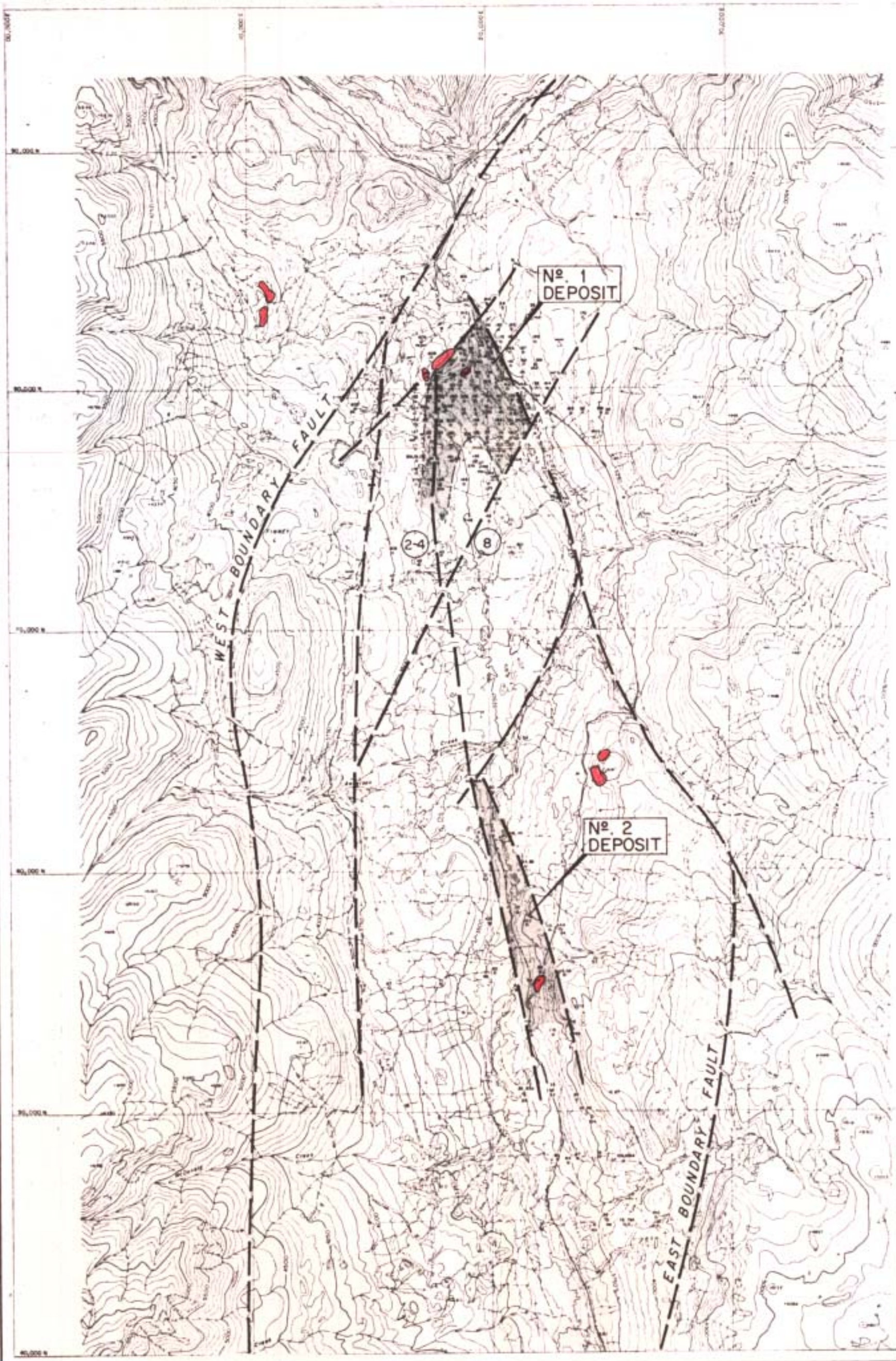
GENERAL DESCRIPTION: Platey mass of pale and dark brown colloform mineral that is dissected by closely spaced, curved, interlocked shatter or shrinkage cracks, the wider ones of which are filled with colloform (wormy) limonite. The limonitization is more intense next to the fractures (dark brown) than in the centres (pale brown) of the polygonal plates that are bounded by the fractures, giving the slide a multibrown giraffe-colouring type pattern.

MINERALS

%		
50	Halloysite (clay)	This slide is a good specimen of halloysite. This clay mineral is distinctive in microscopic characteristics and is generally found in extremely weathered kaolinitic shale.

DISCUSSION

The rock is an extremely WEATHERED CLAY SHALE.



LEGEND

MOST RECENT VOLCANICS
Areas of basalt breccia and/or tephra that includes fragments of Tertiary sedimentary rocks. Generally lying on or in regolith on glaciated (?) bedrock surface.

PRINCIPAL KNOWN AND INFERRED FAULTS

M030 (1)

DOLMAGE CAMPBELL & ASSOCIATES LTD. CONSULTANTS
VANCOUVER, CANADA

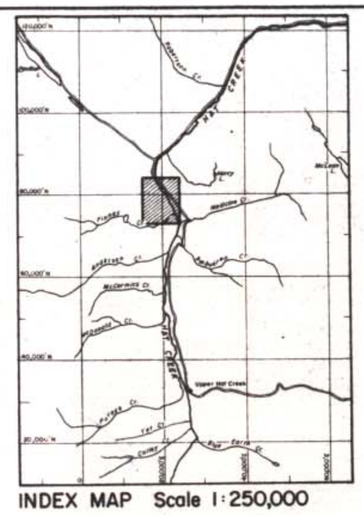
B.C. HYDRO & POWER AUTHORITY
VANCOUVER, CANADA

HAT CREEK PROJECT — GEOLOGY

MOST RECENT VOLCANIC DEPOSITS
(TEPHRA AND/OR OXIDIZED COLDWATER SEDIMENTARY ROCKS)

Mapping by P. J. Street & D. D. Campbell

SCALE : 1" = 4000'	OCT. 28, 1977	FIG. 1



INDEX MAP Scale 1:250,000

WEST BOUNDARY FAULT

SLIDE

AleeceLake LINEAMENT

FAULT ② (MAG)

FAULT ⑥

FAULT ②

FAULT ④

HAT CREEK

TRENCH A

TRENCH B

969

957

970-972

(913-916, 1118-1122)

(1107-1110)

(1154-1156)

(1160-1165)

(1233-1236, 1243)

(1239-1241)

84,000 N

82,000 N

80,000 N

78,000 N

76,000 N

20,000 E

22,000 E

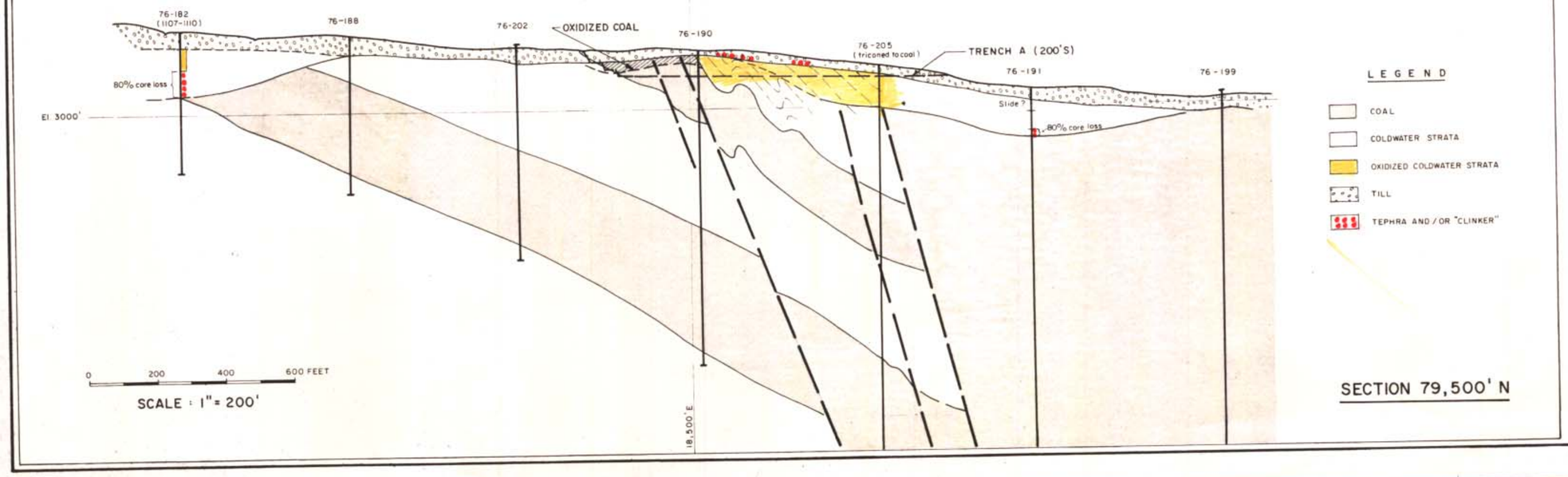
24,000 E

LEGEND

- COAL SUBOUTCROP
- OXIDIZED COLDWATER STRATA (Burnt and/or preglacially weathered)
- OXIDIZED COLDWATER STRATA IN DRILL CORE
- VESICULAR TEPHRA (CLINKER)-LIKE ROCK FRAGMENTS (BOMBS?) IN REGOLITH.
- VESICULAR MATERIAL IN DRILL CORE
- BOTH OXIDIZED STRATA AND VESICULAR MATERIAL INTERSECTED IN HOLE
- 76-182 (1107-1110) 957 — THIN SECTION SPECIMEN LOCATIONS (DRILL HOLE, SURFACE)

CONTOUR INTERVAL 10 FEET

400 0 400 800 1200 FEET



SECTION 79,500' N

DOLMAGE CAMPBELL & ASSOCIATES LTD. CONSULTANTS
VANCOUVER, CANADA

B.C. HYDRO & POWER AUTHORITY
VANCOUVER, CANADA

HAT CREEK PROJECT - No. 1 DEPOSIT

AREAS OF OXIDIZED (BURNT) ROCK

ND30 (2)

SCALE 1"= 400' | OCT. 28, 1977 | FIG. 2