

Original

PETROLOGIC DESCRIPTION OF
AMOCO CATHEDRAL RIVER
NO. 1 SANDS

by

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SUMMARY

Petrographic examination of 43 samples from AMOCO CATHEDRAL RIVER NO. 1 SAND, showed the lithology to be predominately volcanic-rich litharenites or feldspathic litharenites with only minor amounts of arkose, lithic arkose and quartzite.* Typically the sands were compacted with no remaining porosity. Often volcanic rock fragments became incoherent with compaction, molding around grains to form an interstitial matrix. Where compaction did not reduce all intergranular voids, authigenic cements formed. The cements are chlorite/smectite, laumontite, and carbonate. Veins of laumontite/heulandite cut the volcanoclastic sands. These phases also replace preexisting minerals. The most common accessory minerals were a green hornblende amphibole, epidote and opaques (clasts and pyrite framboids).

An abrupt transition, from the volcanic sands, to silty or sandy mudstones occurs in the interval between 7810' and 8500'. Below this level, the dominant lithology is a hematite-rich mudstone with minor distinguishable grains of plagioclase and quartz. Pyrite framboids are common as are other opaques which occur in streaks to form pseudo-laminations.

Grain sizes given are an average size for the sample. Most lithologies (especially above 7810') are poorly sorted with a large range in grain size. Typically more than one rock type is present in any thin section, consequently greater than one lithology is described for any one interval.

*The classification scheme used is Folk, 1968.

CATHEDRAL RIVER SAMPLES

CR. 2290-2320

Feldspathic litharenite: coarse sand (.62 mm), very poorly sorted, subrounded to subangular grains with longitudinal to concave grains contacts.

Detrital grains: volcanic rock fragments - 55%; plagioclase - 20%; quartz - 15%; amphibole - 10%; with minor components of biotite, tourmaline, opaques, apatite.

Very compacted, no visible porosity. Plagioclase is altering to clays, laumontite, and sericite.

Lithic siltstone: medium silt (.15 mm), poorly sorted subangular to subrounded grains floating in a matrix of squished volcanic rock fragments (compacted tuff?).

Detrital grains: volcanic rock fragments - 68%; quartz - 25%; plagioclase - 5%; amphibole - 2%; with minor components of opaques, sphene.

Abundant saussuritization. Zeolite (heulandite?) vein, no visible porosity due to small grain size and compaction.

Granitoid: composed of coarse grained quartz, plagioclase, hornblende, sphene, and biotite.

CR. 2520-2530

Feldspathic litharenite: fine sand (.155 mm), poorly sorted, angular to subrounded grains with longitudinal to concave grain contacts.

Detrital grains: volcanic rock fragments - 60%; plagioclase - 25%; quartz - 10%; biotite - 5%. Minor components: amphibole, epidote, opaques. Plagioclase altering to sericite, minor laumontite.

Zeolite (heulandite) vein cutting the incoherent volcanic rock fragment matrix. Compacted with no visible porosity.

Feldspathic litharenite: very fine sand (.074 mm), poorly sorted, subrounded grains with longitudinal to concave grain contacts.

Detrital grains: volcanic rock fragments - 65%; plagioclase - 25%; quartz - 10%; with minor components of orthopyroxene, epidote, and polycrystalline quartz.

Intergranular clays abundant. Less altered to clays than previous sample as the clays are confined to grain boundaries. Some fragments have amphibole and abundant saussurite so that grains are floating in the saussurite.

Granitoid: coarse grained plagioclase and quartz with minor calcite.

CR. 2530-2540

Arkose: very fine sand (.093 mm), moderately sorted, subrounded grains with longitudinal grain contacts.

Detrital grains: plagioclase - 70%; quartz - 20%; volcanic rock fragments - 10%; with minor amphibole. Plagioclase is altering to sericite.

Minor poikilitic laumontite cement. No visible porosity.

Feldspathic litharenite: medium sand (.39 mm), poorly sorted, subrounded grains with longitudinal to concave contacts.

Detrital grains: volcanic rock fragments - 48%; plagioclase - 35%; quartz - 10%; amphibole - 5%; opaques - 2%; with minor epidote and biotite.

Matrix, composed of squished and compacted volcanic rock fragments, is extremely altered to brown clays. No visible porosity.

Feldspathic litharenite: coarse sand (.62 mm), poor to moderately sorted, subrounded to rounded grains with longitudinal to concave grain contacts.

Detrital grains: volcanic rock fragments - 57%; plagioclase - 30%; quartz - 10%; opaques - 3%; with minor amounts of biotite, epidote, and hornblende. Plagioclase is altered to sericite, kaolinite, and laumontite.

Minor intergranular laumontite is present. Matrix is composed of compacted volcanic rock fragments. No visible porosity.

CR. 2820-2830

Litharenite: fine sand (.234 mm), very poorly sorted, subangular to subrounded grains floating in a matrix of incoherent volcanic rock fragments.

Detrital grains: volcanic rock fragments - 65%; plagioclase - 20%; quartz - 15%; with minor amphibole, opaques, biotite, epidote and polycrystalline quartz.

Hematitic rich matrix, very compacted with no visible porosity.

Feldspathic litharenite: medium sand (.312 mm), moderately sorted, subrounded to rounded grains with longitudinal to concave grain contacts.

Detrital grains: volcanic rock fragments - 70%; plagioclase - 25%; quartz - 5%; with minor biotite, amphibole, polycrystalline quartz. Minor poikilitic laumontite cement with zeolite (clinoptilolite?) vein cutting the matrix. Plagioclase is altered to kaolinite (brown clays) and sericite.

Compacted with no visible porosity.

CR. 2830-2840

Lithic arkose: medium sand (.30 mm), poorly sorted, subangular to subrounded grains with concave grain boundaries.

Detrital grains: plagioclase - 45%; volcanic rock fragments - 35%; quartz - 20%; with minor biotite (altering to chlorite) and opaques. Plagioclase is altered to kaolinite (brown clays). Compacted with no visible porosity.

Feldspathic litharenite: fine sand (.15 mm), poorly sorted, subrounded grains, with concave grain contacts.
 Detrital grains: volcanic rock fragments - 60%; plagioclase - 30%; quartz - 5%; amphibole - 5%; with minor biotite (altering to chlorite). Plagioclase altering to kaolinite.
 The sample is characterized by a ubiquitous alteration to brown clays as previous samples. Compacted with no visible porosity.

Litharenite: very fine sand (.10 mm), poorly sorted subrounded grains floating in a hematitic, clay rich matrix (compacted and altered volcanic rock fragments).
 Detrital grains: volcanic rock fragments - 75%; quartz - 20%; plagioclase - 5%; with minor amphibole and opaques. Plagioclase is altered to kaolinite (brown clays).
 Zeolite (heulandite?) vein and isolated patches of carbonate. Compacted with no visible porosity.

CR. 3100-3110

Feldspathic litharenite: coarse sand (.62 mm), moderately sorted, subangular to rounded grains with longitudinal to concave grain contacts.
 Detrital grains: volcanic rock fragments - 55%; plagioclase - 25%; quartz - 15%; amphibole - 5%; with minor epidote, biotite, polycrystalline quartz, and opaques.
 Pervasive alteration to yellow-brown clays with clays rimming grains. Minor laumontite cement. Zeolite (heulandite?) vein with carbonate occurring in the center of the vein cuts the sample. Compacted with no visible porosity.
 Additional chips of this composition are very poorly sorted (.15 -1.5 mm) with abundant intergranular yellow-brown clays with or without saussurite.

Litharenite: fine sand (.15 mm), poorly sorted, subrounded grains with longitudinal to concave grain contacts.
 Detrital grains: volcanic rock fragments - 68%; plagioclase - 10%; quartz - 15%; hornblende - 7%; with minor polycrystalline quartz.
 Grains occur in a matrix of squished volcanic rock fragments with abundant clays. Zeolite (heulandite?) veins cut the sample. Very compacted with no visible porosity.

CR. 3150-3160

Feldspathic litharenite: fine sand (.19 mm), poorly sorted subrounded grains with longitudinal to concave grain contacts.

Detrital grains: volcanic rock fragments - 62%; plagioclase - 25%; quartz - 10%; amphibole - 3%; with minor opaques, biotite and epidote.

Similar to previous sample with incoherent rock fragments altering to clays. Clays are rimming grains. Minor laumontite cement and heulandite(?) as a vein mineral. Abundant saussurite. Compacted with no visible porosity.

Additional chips of this composition are present which differ in grain size [coarse silt (.062mm)], and in amounts of constituents (volcanic rock fragments - 65%; quartz - 20%; plagioclase - 15% = litharenite). Some chips are very fine grained and floating in a matrix of hematite and clays.

CR. 3160-3170

Lithic arkose: coarse sand (.7 mm), well sorted, angular to subrounded clasts with longitudinal grains contacts.

Detrital grains: quartz - 50%; plagioclase - 20%; volcanic rock fragments - 15%; amphibole - 15%; with minor epidote and opaques.

Intergranular clays compacted with no visible porosity.

Sandy siltstone: coarse silt (.05 mm), well sorted angular to subrounded grains floating in a clay rich matrix.

Detrital grains: quartz; plagioclase; volcanic rock fragments; amphibole; and opaques.

Clay rich sediment cut by veins of laumontite and opaques.

Feldspathic litharenite: coarse sand (.60 mm), very poorly sorted angular to subrounded grains with longitudinal grain contacts.

Detrital grains: plagioclase - 30%; quartz - 30%; volcanic rock fragments - 31%; amphibole - 3%; biotite - 2%; epidote - 2%; sphene - 1%; and opaques - 1%; with minor polycrystalline quartz. Incoherent rock fragments comprising matrix. Compacted with no visible porosity.

CR. 3170-3200

Feldspathic litharenite: fine sand (.16 mm), poorly sorted, subangular to rounded grains with longitudinal to concave grain contacts.

Detrital grains: volcanic rock fragments - 60%; plagioclase - 25%; quartz - 15%; with minor amounts of epidote, amphibole, opaques, biotite, polycrystalline quartz, and sphene.

Plagioclase is altered to sericite, laumontite and kaolinite. Matrix consists of squished volcanic rock fragments containing abundant clays. Very compacted with no visible porosity.

Arkose: fine sand (.16 mm), poorly subangular to subrounded grains with longitudinal to concave grain contacts.

Detrital grains: plagioclase - 60%; quartz - 20%; volcanic rock fragments - 15%; with minor epidote, muscovite, opaques and

polycrystalline quartz. Plagioclase is altered to sericite and kaolinite.

Minor poikilitic laumontite cement with a vein of heulandite(?). Additional chips of this lithology are present but differ in grain size (medium silt - .03 mm) and have a greater percent of amphibole and epidote grains. Abundant hematite and clays may also be present. All samples are compacted with no visible porosity.

CR. 3200-3210

Feldspathic litharenite: medium sand (.31 mm), poor to moderately sorted subrounded to rounded grains with longitudinal to concave grain contacts.

Detrital grains: volcanic rock fragments - 50%; plagioclase - 45%; quartz - 5%; with minor epidote, amphibole, polycrystalline quartz, biotite, sphene and opaques.

Minor laumontite cement. Intergranular clays are present. Some chips of this lithology have greater amounts of laumontite cement with less volcanic rock fragments, or volcanic rock fragments compacted so as to fill intergranular voids. Compacted with no visible porosity.

Lithic arkose: coarse siltstone (.062 mm), poorly sorted, angular to subrounded grains with longitudinal to concave grain contacts.

Detrital grains: quartz - 40%; plagioclase - 30%; volcanic rock fragments - 25% amphibole - 5%; with minor biotite, epidote and opaques.

Abundant intergranular clays from the breakdown of volcanic rock fragments. Many rock fragments incoherent and filling voids. Minor laumontite cement and carbonate clasts. Compacted with no visible porosity.

CR. 3390-3400

Lithic arkose: medium sand (.31 mm), poorly sorted, subangular to subrounded grains with longitudinal to concave grain contacts.

Detrital grains: plagioclase - 35%; volcanic rock fragments - 30%; quartz - 25%; amphibole - 10%; with minor epidote, biotite, metamorphic rock fragments, opaques, carbonate and saussurite. Plagioclase altered to kaolinite and laumontite, volcanic rock fragments altered to laumontite.

Clays rimming grains with poikilitic laumontite cement.

Feldspathic litharenite: medium silt (.031 mm), moderately sorted, subangular to subrounded grains with longitudinal to concave grain contacts.

Detrital grains: quartz - 50%; volcanic rock fragments - 25%; plagioclase - 15%; amphibole - 10%; with accessory phases as previous sample.

Greater amount of hematite in groundmass clays. Compacted with

no porosity.

Subarkose: fragment composed of fine sand (.234 mm) clasts of polycrystalline quartz (metamorphic rock fragment), plagioclase, and quartz; totally carbonate cemented, no visible porosity.

CR. 3400-3410

Lithic Arkose: very fine sand (.12 mm), poorly sorted, subangular to rounded grains with longitudinal to concave grain contacts.
 Detrital grains: plagioclase - 50%; volcanic rock fragments - 23%; quartz - 25%; amphibole - 2%; with minor epidote and opaques.
 Plagioclase altered to kaolinite. Minor poikilitic laumontite cement. Ubiquitous dusty brown alteration with minor clays rimming grains. Abundant saussurite. The thin section is so thick that most minerals display third order colors, therefore is it nearly impossible to distinguish with certainty the other rock chips. No visible porosity.

CR. 3500-3510

Lithic arkose: coarse sand (.78 mm), very poorly sorted, subrounded grains with longitudinal grain contacts.
 Detrital grains: plagioclase - 45%; volcanic rock fragments - 45%; quartz - 10%; with minor amphibole, epidote, opaques. Plagioclase altered to kaolinite and laumontite.
 Ubiquitous alteration to brown clays. Minor intergranular calcite.

Lithic arkose/feldspathic litharenite: medium sand (.40 mm), poor to moderately sorted, subangular to rounded grains with longitudinal to concave grain contacts.
 Detrital grains: plagioclase - 30%; quartz - 30%; volcanic rock fragments - 30%; amphibole - 5%; epidote - 5%; with minor clinopyroxene, saussurite, metamorphic rock fragments, and calcite. Plagioclase altered to kaolinite.
 Yellow/brown clays rimming grains and sprinkled throughout sample. Compacted with minor intergranular laumontite cement. No visible porosity.

Zeolitic vein fragment: Minor plagioclase lath altered to zeolites and kaolinite, quartz, hornblende and biotite with a matrix of laths of heulandite?/laumontite?

CR. 3560-3570

Lithic arkose: fine sand (.217 mm), poorly sorted subangular to rounded grains with longitudinal to concave grain contacts.
 Detrital grains: plagioclase - 40%; volcanic rock fragments - 40%; quartz - 20%; with minor clinopyroxene, biotite, polycrystalline quartz and opaques. [Amounts of constituents vary throughout the sample]. Plagioclase altered to kaolinite.
 "Fresher" appearance than previous samples, although a thin coating of brown clays is present. Yellow/brown clays rimming some grains. Minor poikilitic laumontite cement, with minor calcite cement.

Additional chips of this composition are present but differ: in the amount of brown clays (kaolinite); plagioclase altered to zeolites and kaolinite; presence of biotite, sericite/muscovite, amphibole, epidote, or tourmaline; or compacted volcanic rock fragments forming matrix. No visible porosity in any sample.

Altered igneous rock - basalt? Plagioclase laths and microphenocrysts altered to kaolinite and zeolites, plus epidote in a hematitic-clay rich groundmass. Laumontite/heulandite vein cutting sample.

Metamorphic Rock Fragment: polycrystalline quartz + biotite + plagioclase + opaques, aligned.

Siltstone: coarse silt (.062 mm), quartz and plagioclase grains floating in a matrix of hematitic clays with calcite cement.

CR. 4000-4010

Siltstone: medium silt (.031 mm), moderately well, sorted subangular to subrounded grains floating in a clay rich matrix (VRF's?).

Detrital grains: quartz; plagioclase; biotite; amphibole; and opaques. Abundant yellow clays.

Additional fragments have distinguishable grains in the medium sand range (.31 mm) = sandy siltstone. Detrital grains: quartz, plagioclase, polycrystalline quartz, amphibole, epidote. Very compacted with no visible porosity. Very poorly sorted.

Arkose: coarse grains of plagioclase - 50%; and quartz - 50%; with minor amphibole and intergranular detrital clays.

CR. 5000-5010

Siltstone: fine silt (.012 mm), moderately to well sorted grains floating in a clay rich matrix.

Detrital grains: plagioclase; quartz; opaques; amphibole.

Minor carbonate and saussurite in addition to clays.

Other chips have more abundant authigenic chlorite/smectite growing radially from grains and less detrital clays/compacted VRF's. Zeolites (laumontite/heulandite?) surrounding some grains and replacing grains. Compacted with no visible porosity.

CR. 5630-5640

Lithic arkose: very fine sand (.124 mm), poorly sorted, subrounded grains with concave grain contacts.

Detrital grains: volcanic rock fragments - 30%; plagioclase - 25%; quartz - 15%; laumontite - 30% with minor clinopyroxene, epidote, opaques, amphibole, chlorite and tourmaline. Plagioclase altered

to laumontite, volcanic rock fragments altered to chlorite-rich clays. Poikilitic laumontite (heulandite?) cement throughout matrix and in volcanic rock fragments. Zeolitic vein (laumontite/heulandite?) cuts sample. Green clays throughout sample but concentrated in the volcanic rock fragments. Compacted with no visible porosity.

Siltstone: coarse silt (.062 mm), moderately well sorted, subrounded grains with longitudinal grain contacts.

Detrital grains: volcanic rock fragments - 50%; quartz - 30%; plagioclase - 20%; with abundant clays and accessory minerals as above, plus polycrystalline quartz.

Minor laumontite cement with abundant clays (detrital) rimming grains, with a hematitic alteration. Some chips have essentially all hematitic rich clays with few distinguishable grains.

Very fine grained, compacted and no visible porosity.

Feldspathic litharenite: medium sand (.31 mm), moderately sorted, subangular to subrounded grains with longitudinal to concave grain contacts.

Detrital grains: volcanic rock fragments - 50%; quartz - 30%; plagioclase - 20%; with minor epidote, chlorite and opaques.

Hematitic rich clays at grain boundaries in addition to saussurite. Compacted with no visible porosity.

CR. 5640-5650

Feldspathic litharenite: fine sand (.156 mm), moderately sorted, subrounded grains with longitudinal to concave grain contacts.

Detrital grains: volcanic rock fragments - 60%; plagioclase - 25%; quartz - 15%; with minor chert, polycrystalline quartz, amphibole; epidote, opaques (plus pyrite framboids), biotite and chlorite. Plagioclase altered to zeolites. Abundance of saussurite.

Matrix consists of hematitic rich clays (yellow and brown) lining grains and filling interstices. Minor authigenic clay (chlorite/smectite?) development, and minor zeolites in groundmass. No visible porosity.

Additional chips of this lithology are present but differ in grains size (.062 mm, very fine sand/coarse silt). Zeolite veins (laumontite/heulandite?) are present. One fragment consists totally of crystalline zeolites (heulandite/laumontite?). One fragment contains minor carbonate cement. Siltstones are also present, as described above.

CR. 5830-5840

Litharenite: medium sand (.31 mm), poor to moderately sorted, subangular to rounded grains with concave grain contacts.

Detrital grains: volcanic rock fragments - 70%; plagioclase - 20%; quartz - 10%; with minor polycrystalline quartz, chert, epidote, biotite, chlorite, or hornblende. Plagioclase is fresh or altered to zeolites. VRF's altered to clays.

Groundmass consists of compacted and crushed volcanic rock fragments (VRF's) with microphenocrysts of plagioclase. Clays are present intergranularly from the breakdown of VRF's. Amount of clays and grain size is variable throughout the sample. One chip appears to have authigenic hematitic-rich clay, with radial fibers filling interstices. Clinoptilolite (heulandite?) vein present. Compacted with no visible porosity.

Additional fragments of this lithology have all the plagioclase altered to zeolites, brown clays rimming grains with kaolinitic alteration throughout the sample. Hornblende and epidote may or may not be present.

Fragments of a zeolitic (heulandite/clinoptilolite?) vein and a hematitic-rich siltstone (as above) are also present.

CR. 5840-5850

Arkose: fine (.186 mm) to medium (.312 mm) sand, moderately sorted, subrounded grains with longitudinal to concave grain contacts.

Detrital grains: plagioclase - 85%; volcanic rock fragments - 10%, quartz - 3%; amphibole - 2%; with minor opaques, biotite, epidote and chlorite. Plagioclase altered to zeolites and kaolinite. Abundant alteration to brown clays (kaolinite), with poikilitic laumontite (heulandite?) cement. Compacted with no visible porosity.

Litharenite: medium sand (.312 mm), poorly sorted subangular grains floating in a groundmass of squished and compacted volcanic rock fragments.

Detrital grains: volcanic rock fragments - 85%; plagioclase - 10%; quartz - 5%; with minor biotite. Rock fragments altered to clays and saussurite. Pyrite framboids are also present. Authigenic zeolites are present in groundmass, intergranular and replacing rock fragments. Authigenic clays rimming grains with zeolites filling voids. Very compacted, no visible porosity.

Sandy siltstone: fine sand (.156 mm) grains floating in a clay rich matrix (squished volcanic rock fragments).

Detrital grains: quartz, polycrystalline quartz, plagioclase, opaques, epidote, and chlorite.

Some fragments have a greater amount of opaques and hematite, and chlorite with minor zeolites rimming and replacing grains. Compacted with no visible porosity.

Altered rhyolite fragment: plagioclase laths oriented in a matrix of chlorite/smectite (produced from devitrification of glass and alteration of groundmass material). Minor amphibole, biotite and quartz is present. Groundmass altered to clays and zeolites.

CR. 6070-6100

Siltstone: coarse silt (.062 mm) moderately sorted, subrounded grains with concave grain contacts.

Detrital grains: volcanic rock fragments - 70%; quartz - 20%; plagioclase - 10%; with minor biotite, pyrite framboids, amphibole. VRF's altered to clays, minor saussurite and zeolites.

VRF's compacted and squished to fill interstices, biotite bent. Very compacted. Minor authigenic chlorite/smectite intergranularly. Some grains are compacted so as to produce lineation within the samples by alignment of opaques and clays. Carbonate cement may or may not be present. Extremely compacted with no visible porosity.

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Sandy mudstone: hematitic-rich clays forming a groundmass with minor distinguishable grains of quartz, polycrystalline quartz, plagioclase, pyrite framboids and opaques. Zeolitic vein (clinoptilolite?) fragment is also present.

CR. 6100-6130

Siltstone/Feldspathic litharenite: medium silt (.031 mm), moderately sorted, subrounded grains with longitudinal to concave grain contacts. Detrital grains: volcanic rock fragments - 50%; quartz - 30%; plagioclase - 20%; with minor biotite, epidote and pyrite framboids. VRF's incoherent and forming matrix. Abundant clays rimming grains. Minor authigenic chlorite filling interstices. Extremely compacted, no visible porosity.

Additional fragments of this composition may have less interstitial VRF's comprising matrix and a greater amount of authigenic chlorite and zeolites in interstices. Zeolites form plagioclase and as discrete clasts. Grain size is variable, as is the amount of saussurite and hematite and carbonate. Carbonate totally cements some fragments. Veins of clinoptilolite/heulandite? with or without carbonate.

CR. 6800-6810

Siltstone/Litharenite: coarse silt (.062 mm), moderately well sorted, subrounded grains with longitudinal to concave grain contacts in a matrix of compacted volcanic rock fragments. Detrital grains: volcanic rock fragments - 55%; quartz - 30%; plagioclase - 15%; with minor epidote, amphibole, carbonate, chlorite, pyrite framboids. Plagioclase altered to zeolites, VRF's altered to clays.

Variable degrees of saussurite and intergranular volcanic rock fragments. Grain size varies but lithology remains constant. Extremely compacted with no visible porosity.

Arkose: very fine sand (.124 mm), moderately sorted, subrounded grains floating in carbonate cement.

Detrital grains: plagioclase - 60%; volcanic rock fragments - 20%; quartz - 20%; with minor opaques.

Totally carbonate cemented, with no visible porosity.

Additional fragments of this lithology contain amphibole and/or epidote, with no calcite cement. Here compacted VRF's form matrix. Minor zeolites are present in the groundmass and as alteration products of plagioclase.

Hematitic-rich siltstone fragments are also present.

CR. 7010-7020

Litharenite: very fine sand (.093 mm), poorly sorted, subangular to rounded grains with longitudinal to concave grain contacts or floating in a matrix of volcanic rock fragments.

Detrital grains: volcanic rock fragments - 65%; quartz - 20%; plagioclase - 15%; with pyrite framboids.

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Variable amounts of hematite and saussurite are present in the groundmass. Plagioclase altered to zeolites as well as VRF's.

Feldspathic litharenite: very fine sand (.124 mm), moderately sorted subangular grains in a matrix of incoherent volcanic rock fragments.

Detrital grains: volcanic rock fragments - 65%; plagioclase - 25%; quartz - 10%.

Similar to the above sample but a greater abundance of volcanic rock fragments (most of which are altered to zeolites and clays), and plagioclase with less quartz. Extremely compacted with veins of opaques.

CR. 7020-7030

Litharenite: very fine sand (.078 mm), moderately sorted, subangular to subrounded grains with longitudinal to concave grain boundaries.

Detrital grains: volcanic rock fragments - 55%; quartz - 30%; plagioclase - 15%; with minor opaque clasts, carbonate and laumontite. Abundant pyrite framboids.

VRF's altered to clays and filling interstices. Clays rimming grains and filling voids. Extremely compacted with no visible porosity.

Additional fragments are also litharenites but variable sizes, fine sand (.234) and medium silt (.031 mm). Accessory minerals include: epidote, biotite, clinopyroxene, opaques, polycrystalline quartz, clay clasts and minor carbonate. Also extremely compacted with no visible porosity. Textural features are as above.

Lithic arkose: medium sand (.468 mm), moderately sorted, subrounded grains with longitudinal to concave grain boundaries.

Detrital grains: plagioclase - 35%; quartz - 35%; volcanic rock fragments 35%; with minor amphibole, biotite, opaques and pyrite framboids (rimmed by sphene). Plagioclase altered to kaolinite, zeolites; biotite to chlorite.

Grains are rimmed by clays in addition to intergranular clays. Compacted with no visible porosity.

CR. 7380-7390

Litharenite: very fine sand (.093 mm), moderately sorted, subangular grains with longitudinal to concave grain contacts in a matrix of incoherent volcanic rock fragments.

Detrital grains: volcanic rock fragments - 65%; quartz - 20%; plagioclase - 15%; with minor clinopyroxene amphibole, epidote, opaques, carbonate, pyrite framboids, chlorite and polycrystalline quartz. Volcanic rock fragments altered to clays and zeolites; plagioclase altered to zeolites.

Abundant intergranular authigenic chlorite/smectite filling interstices, lining grains and replacing clasts. Some clay is hematite rich. Very compacted with no visible porosity.

Feldspathic litharenite: fine sand (.234 mm), moderately sorted, subrounded grains with longitudinal to concave grain contacts.

Detrital grains: volcanic rock fragments - 40%; quartz - 20%; plagioclase - 15%; matrix clays - 25%; with minor polycrystalline quartz, amphibole, epidote and opaques. Greater amount of hematitic-rich clays intergranular and rimming grains. Chlorite/smectite filling interstices. Compacted with no visible porosity.

Siltstone: medium silt (.031 mm), similar in appearance and composition to the litharenite fragment.

CR. 7580-7590

Litharenite: fine sand (.155 mm), moderately sorted, subrounded grains with longitudinal to concave grain contacts.

Detrital grains: volcanic rock fragments - 55%; quartz - 30%; plagioclase - 15%; with minor amphiboles and opaques (as clasts and as pyrite framboids). VRF's altered to clays, plagioclase altered to kaolinite and zeolites.

Compacted, the intergranular hematitic-rich clays appear detrital in origin. No visible porosity.

Feldspathic litharenite: very fine sand (.093 mm), moderately sorted, subrounded grains with concave grain contacts.

Detrital grains: volcanic rock fragments - 50%; plagioclase - 25%; quartz - 25%; with minor polycrystalline quartz, amphiboles, epidote, chlorite clasts and opaques (clasts and framboids). Plagioclase altered to kaolinite, VRF's altered to clays (chlorite/smectite) and zeolites.

Clays rimming grains, incoherent VRF's comprising matrix. Very compacted with no visible porosity.

Arkose: very fine sand (.093 mm), moderately well sorted, subrounded grains floating on a matrix of carbonate (siderite?) cement.

Detrital grains: quartz - 15% plagioclase - 10%; opaques - 10%; carbonate - 65%; with minor amphibole and pyrite framboids.

Totally carbonate cemented with no visible porosity.

CR. 7590-7620

Feldspathic litharenite: very fine sand (.12 mm), moderately sorted, subangular to subrounded grains with longitudinal to concave grain contacts.

Detrital grains: volcanic rock fragments - 45%; plagioclase - 30%; quartz - 20%; polycrystalline quartz - 5%; with minor epidote, opaques, calcite and laumontite. Plagioclase altered to kaolinite as well as VRF's.

Minor micritic calcite and laumontite distributed throughout the slide. Incoherent VRF's forming matrix, very compacted with no visible porosity.

Litharenite: very coarse sand (1.1 mm), poorly sorted, subangular to subrounded grains with concave grain boundaries.

Detrital grains: volcanic rock fragments - 65%; quartz - 20%; plagioclase - 10%; opaques - 5%; with minor chlorite and laumontite.

Plagioclase altered to kaolinite, VRF's altered to kaolinite and zeolites. Patchy micritic calcite in samples as well as laumontite. VRF's incoherent, compacted to produce matrix. No visible porosity.

Altered glass?: vermicular chlorite/smectite masses of radial fibers with minor interstitial hematite and laumontite. Chlorite/smectite - 80%; laumontite - 10%; hematite - 10%. No visible porosity.

CR. 7800-7810

Feldspathic litharenite: fine sand (.21 mm), moderately sorted, subangular to subrounded grains with longitudinal grain contacts. Detrital grains: volcanic rock fragments - 50%; plagioclase - 25%; quartz - 10%; calcite - 15%; with minor chlorite and epidote. Plagioclase altered to kaolinite as well as volcanic rock fragments. Minor authigenic chlorite, cement, and laumontite. Less clays rimming grains. Compacted with no visible porosity.

Silty mudstone: Hematitic clay (.003 mm) rich matrix supporting minor silt (.03 mm) grains. Detrital grains: plagioclase, quartz, epidote, opaques and laumontite. Plagioclase is well twinned and unaltered. Extremely compacted with no visible porosity.

Altered glass?/volcanic: vermicular chlorite/smectite masses of radial fibers with interstitial hematite and laumontite. Chlorite - 80%; laumontite - 10%; hematite - 10%. No visible porosity.

CR. 8500-8510

Silty mudstone: Minor silt (.03 mm) grains floating in a hematite and opaque, clay-rich matrix. Detrital grains: abundant opaques, quartz, and plagioclase. Minor laumontite. Very opaque rich, dispersed throughout sample imparting a near black appearance. No visible porosity.

Altered glass?: vermicular chlorite/smectite masses of radial fibers, with laumontite and opaques interstitially. Chlorite/smectite - 75%; opaques - 15%; laumontite - 10%.

CR. 9080-9110

Sandy mudstone: Very fine sand (.15 mm) grains floating in a hematitic, clay-rich matrix, with streaks of opaques defining lineations. Detrital grains: plagioclase, quartz and opaques. Sample cut by carbonate vein.

Quartzite: Well sorted, rounded grains of quartz with interpenetrating grain contacts. Quartz is full of fluid inclusions. Individual grains .2-.7 mm.

CR. 9400-9410

Silty mudstone: Silt (.02 mm) grains floating in a hematitic, clay-rich matrix with abundant opaques.

Detrital grains: plagioclase, quartz and opaques.

Opaques occur in streaks which define a lineation. Sample cut by varbonate veins, one of which has an inclusion of the vermicular chlorite/smectite. Very compacted with no visible porosity.

Silty mudstone: Silt (.06 mm) grains floating in a laumontite-, clay-rich matrix.

Detrital grains: plagioclase, quartz and opaques.

Opaques concentrated in the center of clasts and clays dispersed throughout sample. Compacted with no visible porosity.

Carbonate vein fragment.

CR. 9810-9820

Sandy mudstone: Very fine sand (.07 mm) grains floating in a matrix of hematite-rich clays and opaques.

Detrital grains: plagioclase, quartz, opaques and calcite.

Minor calcite and laumontite occur as replacement products of preexisting grains. Opaques streaked and define a lineation.

Very compacted with no visible porosity.

Altered glass?: vermicular chlorite/smectite masses of radial fibers with hematite filled interstices. Chlorite/smectite - 85%; hematite - 15%.

Carbonate vein fragment with comb structure.

CR. 10010-10100

Silty mudstone: Minor silt (.05 mm) grains floating in a hematite and clay-rich matrix.

Detrital grains: quartz, plagioclase, and opaques (plus pyrite framboids).

Streaks of opaques define a lineation. Minor laumontite and carbonate. Carbonate vein cuts sample. Vein also contains euhedral quartz.

CR. 10540-10550

Subarkose: fine sand (.17 mm), moderately well sorted, angular to subrounded grains with longitudinal grain contacts.

Detrital grains: quartz - 75%; plagioclase - 25%. Plagioclase replaced by laumontite and calcite. Pyrite framboids are also present. Authigenic laumontite, carbonate, and chlorite/smectite are interstitial to grains.

Compacted and cemented with no visible porosity.

Sandy mudstone: very fine sand (.1 mm) floating in a hematite and clay-rich matrix with opaques.

Detrital grains: plagioclase, quartz and opaques (+ pyrite framboids). Amount of clastic grains and opaques varies throughout sample. Opaques are streaked to form lineations. Minor laumontite and calcite are dispersed throughout the sample. Sparry calcite veins cut some fragments. Compacted with no visible porosity.

CR. 10510-10540

Arkose: fine sand (.12 mm), moderately well sorted, subrounded grains with longitudinal grain contacts.

Detrital grains: Plagioclase - 70%; quartz - 30%; with minor opaques (leucoxene, hematite) and chlorite. Carbonate replacing plagioclase. Interstitial laumontite and carbonate. Minor chlorite (after biotite) and in a vein. Zeolitic veins. Compacted, cemented with no visible porosity.

Sandy mudstone: Very fine sand (.07 mm), subrounded grains floating in a hematite, clay-rich matrix or with longitudinal grain contacts.

Detrital grains: plagioclase, quartz, chlorite, and opaques. Opaques often streaked to define a lineation. Laumontite and minor carbonate within matrix.

CR. 11000-11010

Sandy mudstone: very fine sand (.01 mm) floating in a hematite, clay-rich matrix.

Detrital grains: plagioclase, quartz, chlorite, and opaques, which vary in amount throughout the sample. Plagioclase altered to laumontite.

Streaks of opaques define lamination. Laumontite and carbonate occur in the matrix. Compacted with no visible porosity.

Zeolitic vein (laumontite/heulandite?) fragment composed of zeolite crystals.

CR. 11010-11020

Silty mudstone: medium silt (.01 mm) floating in a hematite, clay-rich matrix.

Detrital grains: quartz, plagioclase and opaques (+ pyrite framboids). Plagioclase altered to laumontite and calcite. Streaks of opaques form lineations. Laumontite and minor calcite interstitially.

Additional fragments of the mudstone have carbonate veins cutting the sample. The carbonate is sparry and grew in a comb structure. The fragment is slightly coarser grained (.1 mm), has abundant pyrite framboids and matrix carbonate and laumontite.

CR. 12000-12010

Silty mudstone: medium silt (.02 mm) floating in a hematitic, clay-rich matrix.

Detrital grains: plagioclase, quartz, and opaques.

Streaks of opaques, up to 1 mm in cross-section, define a lamination. Minor laumontite and calcite is present in the matrix. No visible porosity.

CR. 13280-13310

Lithic arkose: coarse sand (1.4 mm), poorly sorted, subangular to subrounded grains with longitudinal grain contacts.

Detrital grains: plagioclase - 65%; volcanic rock fragments - 30%; quartz - 5%; with minor epidote, devitrified glass, opaques and chlorite. Plagioclase altered to kaolinite and laumontite.

Carbonate and laumontite veins cut the sample. Compacted with no visible porosity.

Silty mudstone: medium silt (.01 mm) floating in a hematitic, clay-rich matrix.

Detrital grains: quartz, epidote, and opaques. Minor carbonate. Streaks of opaques define a lineation within the sample.

CR. 13540-13550

Feldspathic litharenite: very coarse sand (1.67 mm), poorly sorted, subrounded to subangular grains with longitudinal to concave grain contacts.

Detrital grains: volcanic rock fragments - 50%; plagioclase - 30%; laumontite - 20%. Plagioclase altered to laumontite. Glass altered to chlorite/smectite. Minor epidote and opaques.

Carbonate as a replacement phase within grains and as veins. Compacted with no visible porosity.

CR. 13550-13560

Silty mudstone: fine silt (.007 mm) floating in a hematitic, clay-rich matrix.

Detrital grains: quartz and opaques.

Laminations defined by more hematitic rich clays and quartz-richer clays. Opaques also form streaks and framboids.

Additional fragments of the mudstone have larger (.04 mm) clasts of quartz and plagioclase with laumontite cement. Opaques also rim grains. Compacted with no visible porosity.

Carboate vein fragment with interstitial sericite(?).

CR. 14240-14290

Silty mudstone: medium silt (.02 mm) floating in a hematitic, clay-rich matrix.

Detrital grains: quartz, plagioclase and opaques.

Opaques occur in streaks which define laminations. Clasts have variable size. Minor calcite is present. Compacted with no visible porosity.

Carbonate vein fragment, with or without laumontite.

Laumontite vein fragments, with or without calcite. These appear to form an intermediate zone between the totally carbonate cemented mudstone and the "pure" mudstone.