Appendix – Locations and Petrographic Descriptions of Tapeats Sandstone Samples

The thin sections of the sixteen (16) rock samples for this study were all mounted on standard 1.5 inch (~38 mm) long by 1.0 inch (~25 mm) wide glass microscope slides. Rock slices were cut perpendicular to the bedding so that the laminations could be viewed in cross-section. Any disruptions of the laminations due to ductile deformation would thus be evident without diminishing the ability to observe any dislocations of grains that might or might not have occurred. However, before the slices were cut from the rock samples using a diamond saw, the rock samples were impregnated under confining pressure with epoxy resin that contained a blue dye. This ensured that grains did not get dislocated or the rock fabrics get distorted during the sawing of the slices. However, this process left the thin sections with a blue dye staining as the surrounding background and in any holes or pores within the rock fabrics. Before cover slips were added, the thin sections were stained so as to make the K-feldspar and calcite in the rock fabrics more easily distinguished. Thus, the K-feldspar grains have a distinctive yellow color and the calcite is pinkish in plane polarized light.

The high resolution digital images of the whole thin sections (reproduced below) were obtained using a digital scanner that had been programmed accordingly. When the rock samples were collected in the field the right sides up (tops) were carefully marked, so that the thin sections were cut perpendicular to the bedding and stratigraphic upwards was marked on the thin sections. Consequently, all the images of the whole thin sections below are oriented with stratigraphic upwards always being to the top of the pages. Thus, most of the whole thin sections are reproduced lengthwise vertically, while some are oriented lengthwise horizontally, so that always stratigraphic upwards is at the top of each image (as annotated with an arrow). Carefully following this procedure allowed for observation of sedimentation features such as bedding planes, cross-laminations, and laminae, as well as the sorting and grading of grain sizes. Furthermore, because the images were cropped to remove extraneous details (such a labels) and then sized equally when placed with their respective petrographic descriptions below, a scale bar has been annotated to each image.

Regional Samples

TSS-01 N 36° 12.784' W 111° 48.411' (N 36.213° W 111.807°)

River Mile 60.1 – River left just below Sixtymile Rapid, at the upstream end of the beach, about 12 m (40 feet) down the stratigraphic section from the top of the cliff-forming unit.

In hand specimen, a laminated sandstone with coarse-grained and finer-grained laminae. Poorly sorted, sub-angular to sub-rounded quartz grains.

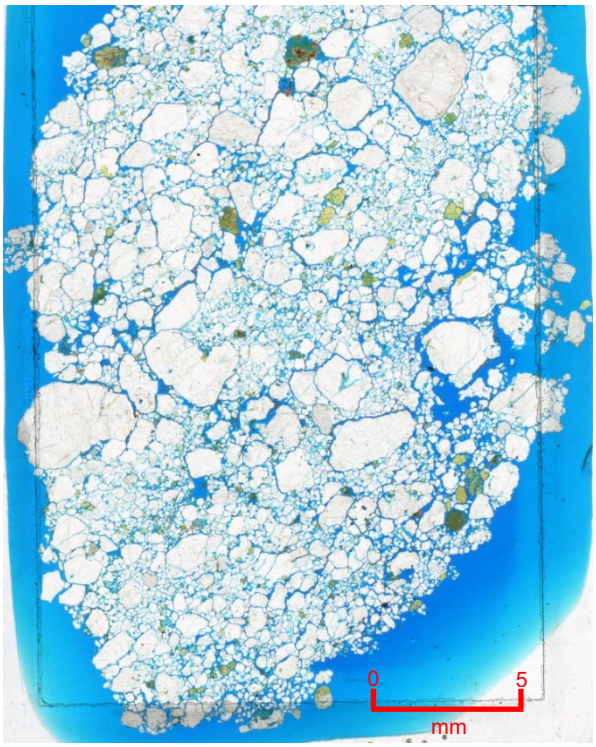
At normal scale, the thin section confirms the poor sorting, although thin (1-2 cm) laminae of finer-grained and coarser-grained sand grains are visible, along with low-angle cross-bedding in the fine-grained layer and one of the two coarser-grained layers. Nevertheless, within the coarser-grained layers the quartz sand grains are poorly sorted because the full range of grain sizes are mixed, whereas the sorting is better in the finer-grained layer where only finer quartz sand grains are present. Occasional K-feldspar grains are scattered through this submature or arkosic quartz sandstone.

Under the microscope, a tightly-packed interlocking mosaic of scattered rounded and sub-rounded to sub-angular and sub-euhedral quartz grains of different sizes from very small to very large (0.05-2.0 mm, ϕ = +4.23 - -1.00, coarse silt to very coarse sand/granule size), sometimes euhedral, sometimes cracked, sometimes with domains or sub-grains of different crystallographic orientations as evidenced by different extinction angles, or even with undulose extinction, sometimes "ghost" rounded edges of original detrital grains with some euhedral overgrowths (cement) so that adjacent grains meet at triple points with roughly equal meeting angles. Some clusters of smaller quartz grains appear to be broken pieces. Occasional very large rounded to sub-rounded quartz grains are surrounded by very small to medium quartz grains tightly packed around them due to overgrowths (cement) on the latter, while in other places there are either lots of very small to small interlocking quartz grains or very small and medium to large irregularly-shaped sub-angular to sub-rounded quartz grains mixed or clustered together. Scattered among the mosaic of quartz grains are a lot of subordinate K-feldspar grains and broken fragments varying in size from very small to large (0.06-1.06 mm, ϕ = +4.05 - -0.08, coarse silt to very coarse sand size), often rounded but sometimes euhedral or sub-euhedral and usually fully altered or altered around edges and even cracked. One possible medium-sized plagioclase grain evidenced by its striped appearance due to telltale multiple twinning under crossed polars. Numerous thin edge-on very small to long (0.3-0.6 mm, ϕ = +1.75 - +0.74) muscovite flakes embedded within the mosaic, wedged primarily between, and sometimes bent or even broken around, the tightly-packed quartz grains, sometimes with frayed ends. One very small face-on muscovite flake is included within a very large sub-euhedral quartz grain. At least one very small, high relief, high birefringent, iron-oxide-stained sub-rounded tabular grain is zircon. The porosity appears variable from ~10% to almost 0%, (average overall ~6.5%) with some pore spaces being large with surrounding euhedral grains a jigsaw puzzle fit if "pushed" back together, but most are trivial, tiny or very small and very thin. Occasional iron-oxide stains around and/or coating grain edges, or staining K-feldspar grains, or even coating or in-filling pore spaces. The sample was forcefully impregnated before sectioning so there is a lot of blue dye between and coating many grains.

TSS-02 N 36° 14.419’ W 112° 28.825’ (N 36.240° W 112.480°)

River Mile 120.8 – River left, coarser-grained sandstone, with similar lithology to samples at Monument Fold (see below), cross-bedded, about halfway down the stratigraphic section from the top of the cliff-forming unit.

At normal scale, the thin section shows the rock fabric is certainly coarse-grained, but is also very poorly sorted, with scattered quartz grains or granules up to 6 mm wide and smaller quartz grains between them ranging down to very fine sand size, and occasional sand-sized K-feldspar grains wedged between them, which makes this a submature or arkosic quartz sandstone.



Under the microscope, the rock appears to have been friable in that the fabric of the rock looks like the grains were pushed apart likely during impregnation prior to the thin section being cut, because if pushed back together they would fit like a jigsaw puzzle. Otherwise, the rock consists of a tightly-fitting interlocking mosaic of quartz grains varying in size from very large to huge grains (up to 3-6 mm wide, ϕ = -1.63 - -2.33 granules to very small pebbles) with surrounding smaller grains (0.07 mm, ϕ = +3.77, very fine sand) to usually small, small-medium or medium-large grains, often rounded to sub-rounded or euhedral (likely due to overgrowths) or irregular with jagged edges, likely due to being fractured and forced apart. Thus, some aggregates of smaller quartz grains appear to be the broken-apart remains of much larger to huge quartz grains. Some huge quartz grains have a patchwork of sub-domains or sometimes sub-grains with different crystallographic orientations and thus extinction angles. Sometimes it is hard to discern whether such huge quartz grains are single grains with the internal patchwork or many smaller grains cemented together in a closely-knit mosaic. Where euhedral or jagged quartz grains meet or would have met if fitted back together triple point junctions are still evident. A few quartz grains have internal "ghost" outlines of the original sub-rounded detrital grains with overgrowths in optical continuity. The few subordinate K-feldspar grains and former laths are usually small (0.07 mm, ϕ = +3.77, very fine sand size) and often rounded, but some are medium to large or even very large (up to 1.00 mm, ϕ = 0.00, coarse sand size), are sometimes cracked, and are usually altered, sometimes to calcite, or are often even veined and/or lined with calcite, and often with some iron oxide staining or speckles. Some K-feldspar grains have ragged edges and one under crossed polars displays cross-hatched twinning. One K-feldspar grain is the rounded end of a former large

lath, while several altered former K-feldspar grains or broken portions of them are included within large and huge quartz grains. Two rounded feldspar grains display multiple-twinning under crossed polars so may be plagioclase. One medium-sized, rounded grain looks like a fine-grained siltstone clast. A few small 0.05-0.25 mm, ϕ = +4.23 - +2.00), thin edge-on muscovite flakes are sometimes frayed at their ends and are often wedged between quartz grains, or even included in medium-sized quartz grains. Calcite not only occurs as alteration after K-feldspar and as veining of K-feldspar grains, but as patches between and lining edges of, or cementing, quartz grains. The porosity varies and averages overall ~6%, indicating the original detrital grains were quartz-cemented into this tightly-fitted mosaic, with later trivial calcite penetrating as cement between a few quartz grains and altering some K-feldspar grains.

TSS-03 N 36° 23.859' W 112° 31.896' (N 36.398° W 112.532°)

River Mile 138 – River right just below Doris Rapid. Cross-bedded, close to the Great Unconformity.

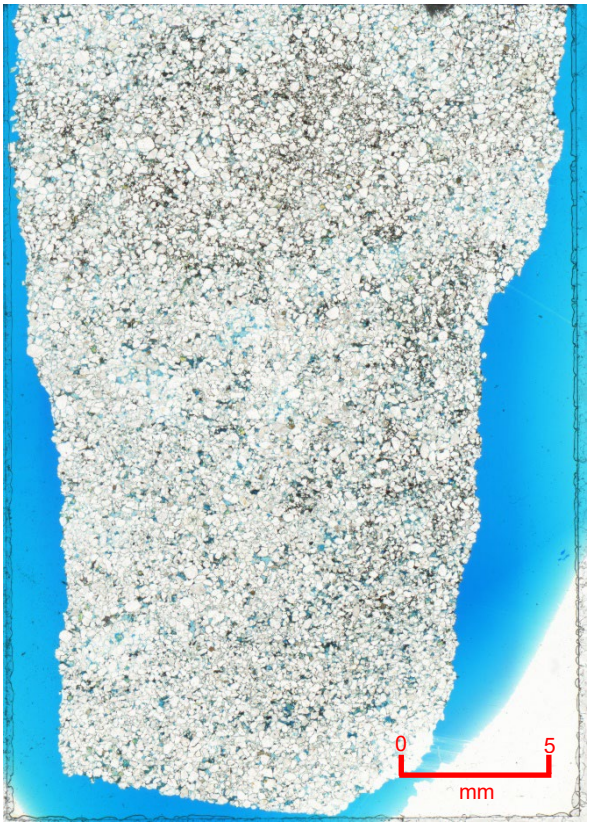
At normal scale, the thin section shows an even, finer-grained, massive sandstone with good sorting due to the quartz grains all being within a narrow size range of predominantly fine sand, with occasional similar-sized altered K-feldspar grains scattered evenly throughout this submature or arkosic quartz sandstone and no laminae evident.

Under the microscope, a tightly-fitting interlocking mosaic of quartz grains varying in size from small to medium to large (0.07-0.68 mm, ϕ = +3.77 - +0.56, very fine to coarse sand size), and sometimes elongated or odd shaped and/or some cracking. Most quartz grains are in the narrow size range of 0.17-0.26 mm (ϕ = +2.57 - +1.95, fine-medium sand). Some quartz grains are euhedral, but many are angular to sub-rounded with irregular edges that sometimes give the impression of being resorbed, and others have internal "ghost" outlines of the original detrital grains and overgrowths in optical continuity that often result in triple point junctions between some such grains. Some large quartz grains are surrounded by other small-medium angular quartz grains with irregular edges. Other large quartz grains contain sub-domains or sub-grains, sometimes with different crystallographic orientations and thus extinction angles. The abundant subordinate K-feldspar grains are usually small, small-medium or medium (0.07-0.75 mm, ϕ = +3.77 - +0.42, very fine to coarse sand size), and rounded, but there is also a very large (0.8 mm, ϕ = +0.33), rounded K-feldspar fragment and a huge (1.8 mm, ϕ = -0.85), corroded K-feldspar lath. Many K-feldspar grains are altered, often with calcite and iron-oxide, especially in cracks and coating the grains. More than a few edge-on muscovite flakes (0.3 mm, ϕ = +1.75, or more long by 0.09 mm thick) are scattered through the mosaic, usually wedged between and sometimes bent around the grains in it, and sometimes with frayed ends. Some are very large to huge and/or thick (up to 2.2 mm long, ϕ = -1.13, and 0.3 mm thick), often expanded between sheets with the ingress of alteration and having frayed ends. Others are broken and altered with accompanying calcite, quartz and iron oxide. One medium-sized quartz grain appears to have included in it a tiny fragment of a face-one biotite flake. There are what appear to be several small (0.15-0.20 mm diameter, ϕ = +2.75 - +2.33) rounded rock fragments accompanied by alteration and iron oxide staining. Calcite and iron oxide are often abundant between and on the edges of grains and sometimes coating K-feldspar grains, in cracks and fractures, and in patches that possibly are infilled pores, thus acting as a cement. The rock was well cemented, but the porosity is difficult to determine and varies, averaging overall ~5.5%. There is some cracking between grains (with blue dye staining now between and on grains due to the forced impregnation prior to the thin section being cut, and if pushed back together they would fit together again like a jigsaw puzzle.

TSS-04 N 36° 23.859’ W 112° 31.896’ (N 36.398° W 112.532°)

River Mile 138 – River right, opposite Doris Rapid. Cross-bedded, stratigraphically higher by 7.5 m (~25 feet).

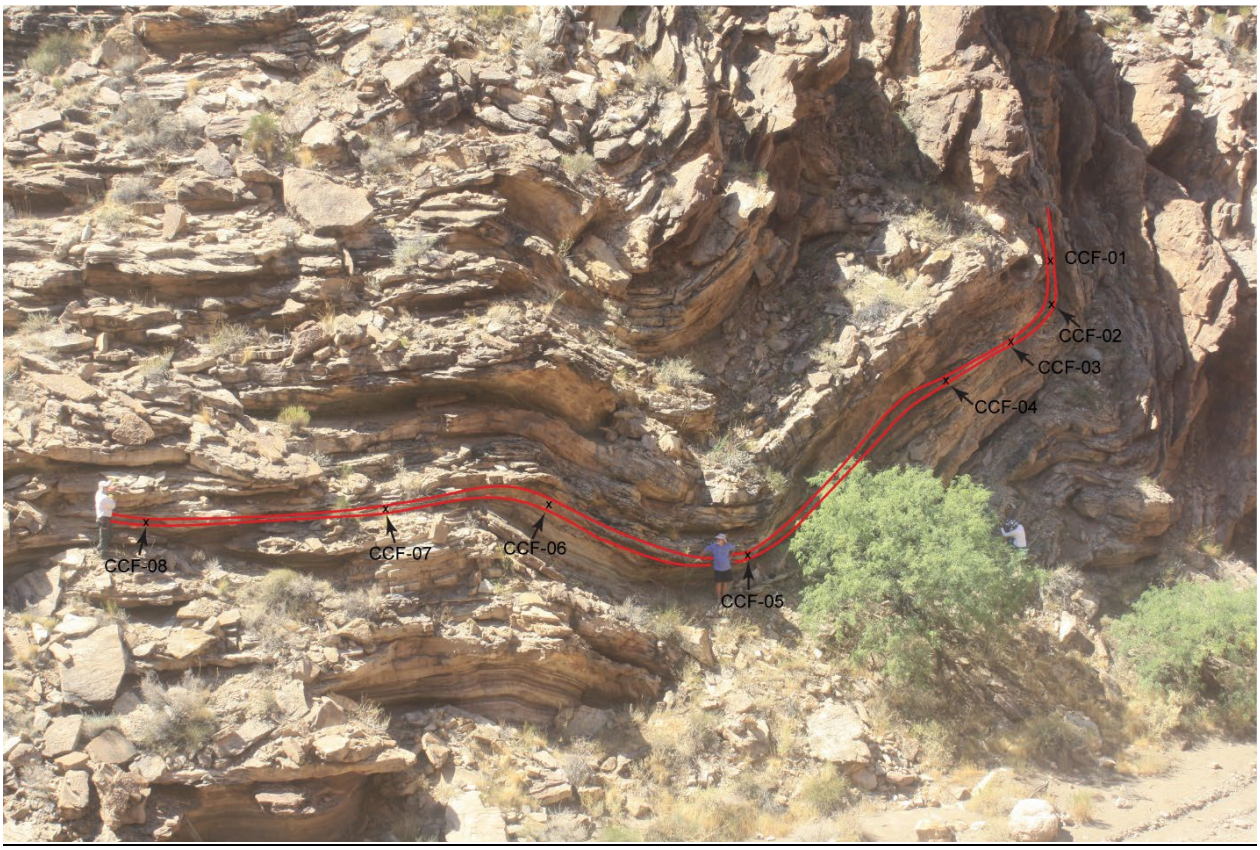
At normal scale, the thin section shows an even-grained massive submature or arkosic quartz sandstone with a mixture of generally small and small-medium subangular to rounded quartz grains with occasional scattered small altered K-feldspar grains and no laminations, but with many very small quartz grains in between the larger grains the rock is not well-sorted.



Under the microscope, an interlocking tightly-fitting mosaic of quartz grains that vary in size within the sample from very small to small-medium, medium-large and large (0.03-0.68 mm, ϕ = +5.01 - +0.56, medium silt to coarse sand sized), with most quartz grains in the 0.3-0.5 mm (ϕ = +1.75 - +1.00, medium sand size) range, and are euhedral or sub-angular to sub-rounded and generally rounded, except for some different and unusual shapes, sometimes elongated, sometimes cracked and some even have broken edges. Grain boundaries show clear outlines, or "ghost" outlines of sub-rounded original detrital grains with overgrowths in optical continuity with each grain, often meeting in triple point junctions. Occasional large irregular quartz grains have an internal patchwork of sub-domains that are various sizes and irregularly shaped, and at different crystallographic orientations and thus extinction angles, within the general mosaic of other small-large, rounded quartz grains. Some quartz grains exhibit undulose extinction. Otherwise generally there is a clear infilling quartz cement between the quartz grains. The edges of some quartz grains give the appearance of resorption, possibly representing solution of the quartz into the original pore water that then precipitated as the infilling overgrowths and quartz cement. Occasional quartz grains or overgrowths appear "dirty", perhaps from included iron oxide. The "dirty" quartz grains could be chert clasts. Some small and medium (0.06-0.33 mm, ϕ = +4.05 - +1.60, coarse silt to medium sand size), rounded K-feldspar grains are evident but are heavily altered. One elongated grain is altered with kaolinite (?) and calcite perhaps after K-feldspar. Another lath-like grain and a fragment are also clearly after K-feldspar. There are numerous small (0.06-0.20 mm, ϕ = +4.05 - +2.33) thin edge-on muscovite flakes, usually bent around and wedged between quartz grains in the mosaic. Other edge-on muscovite flakes are long (0.28-0.35

mm, ϕ = +1.85 - +1.50) or thick and degraded (expanded by alteration). Several small or medium (0.15-0.45 mm, ϕ = +2.75 - +1.15, fine to medium sand size), rounded and/or elongated grains appear to be rock (siltstone/schist?) fragments, often “dirty” from iron oxide. A small (0.10 mm, ϕ = +3.32) rounded oval, high relief, high birefringent, iron oxide stained grain tightly wedged between quartz grains is likely zircon. Small patches of calcite are scattered through the sample and there is a large totally-altered patch that is probably a kaolinite-infilled pore. There is scattered iron-oxide staining, probably with clay minerals (kaolinite and/or illite), between many quartz and other grains, and occasionally coating some quartz and other grains. There is virtually no remaining apparent pores, although since the grain size is very small, the porosity might be "hidden" by stacking of the silt grains which are tinier that the 30-micron slide thickness. Nevertheless, the rock was well cemented, so the porosity is difficult to determine as it varies, averaging overall ~0.5%. There is some cracking between grains.

Carbon Canyon Fold (River Mile 65) Samples



CCF-01 N 36° 09.268’ W 111° 49.806’ (N 36.155° W 111.830°)

Bed 23 cm (~9 inches) thick, part of the vertical limb of the main fold, sampled at 1.2 m (4 feet) above the fold hinge. Strike N350°, dip 88°, both of which are bed structural measurements. The folded beds sampled appear to be 10-12 meters (~33-39 feet) from the top of the cliff-forming unit.

At normal scale, the thin section shows a massive, poorly sorted sandstone with quartz grains of various sizes, the coarser grains scattered between the randomly distributed medium and fine grains. There is a hint of cross-lamination marked by consistent subtle alignments of the coarser quartz grains, and the occasional K-feldspar grains evenly scattered through the rock fabric indicate this is a submature or arkosic quartz sandstone.

Under the microscope, the sample consists of interlocking tightly-fitting mosaics of quartz grains of various sizes (0.08-1.44 mm, ϕ = +3.64 - -0.53, very fine to very coarse sand size) and configurations. Some large (1.09-1.44 mm, ϕ = -0.12 - -0.53, very coarse sand size) sub-angular to rounded quartz grains, some consisting of sub-grains or sub-domains (with irregular or “ameboid” edges) at different crystallographic orientations and thus extinction angles, are surrounded and molded around them by tightly-packed mosaics of medium (0.56-0.76 mm, ϕ = +0.83 - +0.40, coarse sand size) subangular or smaller (0.08-0.48 mm, ϕ = +3.64 - +1.06, very fine to medium sand size) quartz grains (the latter like a glomerocryst), some with internal crack traces, also at different crystallographic orientations and extinction angles. Other large quartz grains have “ghost” rounded outlines of the original detrital grains within them, with overgrowths on those original detrital grains that meet at triple point junctions. Elsewhere in the sample the tightly-packed mosaic consists of small or medium, or a variety of different sizes of, sub-angular to sub-rounded or rounded quartz grains with or without different extinction angles or undulose extinction and often meeting at triple points with occasional “ghost” outlines present. Some patches of the mosaic appear to be recrystallized as they consist of small quartz grains with sharp euhedral contacts meeting at triple points, while some large angular fractured quartz grains display evidence of healing along the fractures with many tiny quartz sub-grains with different extinction angles, the large grains

being in triple point contacts with surrounding smaller quartz grains. Some larger quartz gains exhibit undulose extinction. Many K-feldspar rounded grains of various sizes (0.05-0.67 mm, ϕ = +4.23 - +0.58, coarse silt to coarse sand size) are scattered throughout, and are a part of, wedged in, the mosaic, most being small or medium and sub-rounded while others appear to be small angular fragments, such that several large rounded and cracked K-feldspar grains have K-feldspar fragments nearby. This is also apparent from the K-feldspar grains occurring in three distinct size groupings – many small grains and fragments (0.05-0.15 mm, ϕ = +4.23 - +2.75), a few medium sized grains (0.20-0.28 mm, ϕ = +2.33 - +1.85), and many larger grains and former laths (0.41-0.67 mm, ϕ = +1.29 - +0.58). Two or more K-feldspar grains retain part of their normal tabular habit. Several small (0.10-0.15 mm, ϕ = +3.32 - +2.75) rounded feldspar grains display multiple twinning under crossed polars and may thus be plagioclase. There are also numerous tiny-small to long (0.07-0.30 mm, ϕ = +3.77 - +1.75) edge-on muscovite flakes wedged between and bent around the quartz and K-feldspar grains in the mosaic, but several tiny-small edge-on muscovite flakes are totally within a quartz grains, while several larger edge-on muscovite flakes have flared ends. Two small (0.05 mm and 0.14 mm wide, ϕ = +4.23 and +2.84) face-on muscovite flakes, one accompanied by a small tabular iron oxide grain, are included in large quartz grains (1.09-1.44 mm, ϕ = -0.12 - -0.53). One very small (0.04 mm, ϕ = +4.64) rounded and one small (0.09 mm, ϕ = +3.47) sub-rounded tabular high relief, high birefringent grains are probably zircon. A small (0.17 mm diameter, ϕ = +2.56) elongated and rounded iron oxide stained grain is likely a rock fragment, while a small (0.13 mm diameter, ϕ = +2.95) sub-rounded, high relief, high birefringent, gray grain is likely sphene. There are some small, definitely original, pores, although there are two large iron-oxide filled/cemented pore areas. Generally, the sample has variable porosity that averages overall ~5%, but the rock was well cemented. There is blue dye staining between and on some grains due to forced impregnation prior to the thin section being cut.

CCF-02 N 36° 09.268' W111° 49.806' (N 36.155° W 111.830°)

Bed 18 cm (~7 inches) thick, sampled right in the hinge of the fold. Dip 19°NW (structural dip).

At normal scale, the thin section shows a massive, non-laminated, poorly sorted sandstone with quartz grains of various sizes, the coarser grains scattered between the randomly distributed medium and fine grains. Occasional K-feldspar grains evenly scattered through the rock fabric indicate this is a submature or arkosic quartz sandstone.

Under the microscope, the sample consists of an interlocking tightly-fitting mosaic of dominant quartz and subordinate K-feldspar grains of various sizes and configurations. These range from large or medium-large (0.80-1.20 mm, ϕ = +0.33 - -0.26, coarse to very coarse sand size) rounded, sub-rounded, "ameboid," sub-angular or even in part euhedral quartz grains, often elongated at an angle to the bedding

and sometimes with internal cracking or appearing broken, sometimes exhibiting undulose extinction or they have irregularly-shaped tiny to small sub-grains/sub-domains with different crystallographic orientations and thus different extinction angles, or with "ghost" outlines of the original detrital grains and overgrowths in optical continuity, to a mosaic of assorted small (0.07-0.24 mm, ϕ = +3.77 - +2.06, very fine to fine sand size), or medium (0.30-0.67 mm, ϕ = +1.75 - +0.58, medium to coarse sand size), sub-angular to rounded or even "ameboid" quartz grains and K-feldspar fragments, sometimes molded around the larger grains, often with different extinction angles and meeting at triple points, or sometimes with overgrowths meeting in a euhedral "lock and key" boundary. Many quartz grains have iron oxide stippling or markings consistent with them being detrital. In some portions of these mosaics the quartz grains, whether large or small, can appear to be slightly elongated and parallel to the bedding, or sometimes at various angles to the bedding. Localized evidence of deformation, sometimes "healed" by recrystallization, such as a "shattered" large elongated sub-angular quartz grain with small ameboid pieces, large sub-euhedral elongated quartz grains cracked into broken fragments with different extinction angles, quartz grains that may have fractures and slid along boundaries with offsets, and a "crazy" mosaic of quartz grains that appear broken with sharp "ameboid" edges but recrystallized as a jigsaw fit with different crystallographic orientations and thus different extinction angles yet meeting at triple points. Small (0.04-0.12 mm, ϕ = +4.64 - +3.06, coarse silt to very fine sand size), medium (0.17-0.25 mm, ϕ = +2.56 - +2.00, fine sand size), and medium-large (0.37-0.88 mm, ϕ = +1.43 - +0.19, medium-coarse sand size), sometimes tabular, angular and sub-angular to rounded K-feldspar fragments (fresh or altered) are common, sometimes appearing to be broken, and in one instance recemented by iron oxide. Some medium-large K-feldspar grains exhibit cross-hatched twinning under crossed polars. One K-feldspar fragment is within a large quartz grain. Large tabular, euhedral or rounded K-feldspar grains, some cracked, usually partly or fully altered, are surrounded by the molded mosaic of small and medium quartz grains. Several possible small (0.17-0.28 mm, ϕ = +2.56 - +1.85, fine to medium sand size) sub-angular to sub-rounded plagioclase fragments, some altered, are evident due to the multiple twinning under crossed polars. Many thin edge-on small to long (0.11-0.42 mm, ϕ = +3.19 - +1.25) muscovite flakes are wedged between and within quartz grains, not always

parallel to bedding but many times at various angles, and sometimes with frayed ends. Several small (0.11 mm, ϕ = +3.19) weathered rock fragments may be composed of schist. Iron oxide is present as linings and filling a pore. A small (0.07 mm long, ϕ = +3.77) thin, tabular, high relief, high birefringent grain is likely zircon. There are some minor tiny pores, but generally the porosity varies, yet averages overall ~5%. There is blue dye staining between and sometimes partially covering some grains due to the forced impregnation prior to the thin section being cut.

CCF-03 N 36° 09.263' W 111° 49.797' (N 36.154° W 111.830°)

2.3 m (7.5 feet) from CCF-02, which was sampled in the hinge of the fold. Bed thickness 14 cm (5.5 inches). Dip 22°SW, strike 255° (structural measurements).

At normal scale, the thin section shows a massive, non-laminated, poorly sorted sandstone with quartz grains of various sizes, the coarser grains scattered between the randomly distributed medium and fine grains. Occasional K-feldspar grains evenly scattered through the rock fabric indicate this is a submature or arkosic quartz sandstone.

Under the microscope, a tightly-packed and interlocking mosaic of groups of similar or different sized, small (0.08-0.24 mm, ϕ = +3.64 - +2.06, very fine to fine sand size), medium (0.26-0.50 mm, ϕ = +1.95 - +1.00, medium sand size), and large (0.53-1.02 mm, ϕ = +0.92 - -0.03, coarse sand size), tabular or sub-euhedral with rounded corners, sub-angular to sub-rounded, ovoid, "ameboid" and rounded quartz grains variously oriented, sometimes with internal tiny to small sub-grains or sub-zones, and often with undulose extinction (occasionally in an hourglass pattern) or different extinction angles, often appearing to be recrystallized or cemented by overgrowths usually in optical continuity (often without "ghost" outlines of the original detrital grains) so as to infill the original inter-grain pores to meet at triple points. In some parts of the mosaic the quartz grains display "lock and key" meetings at triple points or irregular interlocking. Some tabular and elongated quartz grains are subtly parallel or at an angle to the bedding. Large euhedral and rounded quartz grains often have the mosaic of small quartz grains molded around them, but sometimes are odd shapes, or even

squarish, with the original detrital outlines within them and overgrowths in optical continuity interlocking with the surrounding mosaic of quartz and K-feldspar grains. Other large angular-euhedral quartz grains are cemented or recrystallized to interlock with triple points but have some pressure effects at boundaries. There are broken tabular quartz grains, others with cracks, and original detrital quartz grains that are dirty with iron oxide speckles and streaks. Some quartz grains have such dirty detrital cores and original rounded outlines with surrounding clean overgrowths in optical continuity. Other quartz grains have undulose and unusual (irregular) boundaries, or diffuse ("fuzzy") or variable edges. One quartz grain has apparent internal striping. Several large rounded to sub-euhedral quartz grains have embedded small inclusions of K-feldspar (0.10 mm, ϕ = +3.32), muscovite (0.08 mm, ϕ = +3.64) and quartz, or just K-feldspar or muscovite. There are many small (0.04-0.22 mm, ϕ = +4.64 - +2.19, coarse silt to fine sand size), angular, sub-angular and rounded K-feldspar fragments/grains or tabular grains scattered throughout the mosaic, but also some larger (0.29-0.61 mm, ϕ = +1.80 - +0.70, medium to coarse sand size) sub-rounded or rounded grains, all usually being weathered, dirty (from included iron oxide) or altered, and attached to, or even within, quartz grains. One dirty K-feldspar grain even has apparent clean peripheral areas (overgrowths?). Several medium-large (0.34-0.58 mm, ϕ = +1.55 - +0.78, medium to coarse sand size) sub-rounded grains appear to be plagioclase due to the multiple twinning under crossed polars. Many thin edge-on small (0.11-0.25 mm, ϕ = +3.19 - +2.00) and longer (0.57 mm, ϕ = +0.81) muscovite flakes (one other is a thick "book") are either parallel or perpendicular to the bedding and are attached to or even cross-cutting quartz grains and wedged between them. There is one medium (0.47 mm, ϕ = +1.09) rounded weathered rock fragment, one small (0.08 mm, ϕ = +3.64) rounded high relief, high birefringent grain that is probably zircon, a small (0.18 mm, ϕ = +2.48) rounded lozenge-shaped, olive-gray, high relief, high birefringent grain is likely sphene, and there are occasional iron oxide linings of a few grains and in some pores. Porosity is minimal and varies, with only a few tiny to small and tight pores, averaging overall ~5.5%. Generally, there is no pores blue dye staining between and sometimes partially covering some grains, due to the forced impregnation prior to the thin section being cut.

CCF-04 N 36° 09.264' W111° 49.794' (N 36.154° W 111.830°)

3.5 m (12 feet) from CCF-03 and sampled 6 m (19.5 feet) from the hinge of the fold. Bed thickness 14 cm (5.5 inches). Dip 36°E, strike 2° (structural measurements). A few slickensides along dip within the bed below.

At normal scale, the thin section shows a massive, non-laminated, poorly sorted sandstone with quartz grains of various sizes, the coarser grains scattered between the randomly distributed medium and fine grains. There is a hint of low-angle curvilinear cross-laminations, and occasional K-feldspar grains evenly scattered through the rock fabric indicate this is a submature or arkosic quartz sandstone.

Under the microscope, a tightly packed and interlocking mosaic of quartz grains (often “molded” so the grains fit together tightly) of variable sizes in some parts and similar sizes in others [small (0.08-0.23 mm, ϕ = +3.64 - +2.13, very fine to fine sand size) – medium (0.26-0.50 mm, ϕ = +1.95 - +1.00, medium sand size) – large (0.52-1.14 mm, ϕ = +0.95 - -0.18, coarse to very coarse sand size)], rounded and sub-rounded to sub-angular and sub-euhedral to euhedral, with defined edges and internal spotted and linear markings of iron oxide, often defining original detrital grains (“ghost” outlines) and sub-euhedral overgrowths in optical continuity that usually meeting at tightly-fitting triple points. Some large and medium quartz grains have sub-domains with different extinction angles that even match in the sub-rounded sub-zones in different grains. Many to most grains meet at interlocking triple points sometimes to often all in optical continuity, likely due to quartz cement growth. Some larger grains are elongated parallel to bedding, often with both rounded and straight edges, some pronounced. Many overgrowths have straight edges and are euhedral to sub-angular so as to form the cement. Some quartz grains have irregular or embayed edges to ensure they fit together tightly. One very large “dirty” (due to iron oxide specks and streaks) quartz grain has the mosaic molded around it. Several large and medium rounded “dirty” quartz grains (which may be chert clasts) have euhedral clear overgrowths in optical continuity. Some larger quartz grains exhibit undulose extinction. Areas of crypto-silica crystallization/cementation sometimes with iron-oxide stained alteration, and large aggregates of tiny quartz grains (angular to sub-euhedral) that represent tiny sub-zones of recrystallized quartz cementation of the mosaic. Some large subrounded to angular quartz grains interlocking unusually like possible healed fractures with subzones with different extinction angles. A small (0.07 mm, ϕ = +3.77) K-feldspar inclusion in a large quartz grain with internal rounded iron oxide outline of detrital grain with overgrowth in optical continuity. Many small (0.08- 0.23 mm, ϕ = +3.64 - +2.13) and medium (0.26-0.48 mm, ϕ = +1.95 - +1.06) angular to sub-euhedral K-feldspar fragments and some small and large (0.53-0.61 mm, ϕ = +0.92 - +0.70) tabular grains (some elongated) partially sub-rounded, partially sub-euhedral, wedged between quartz grains, and many scattered small, medium and large rounded and sub-rounded K-feldspar grains with iron oxide in cracks/fractures and around boundaries and the mosaic of quartz grains fitting tightly around them (likely

by quartz grain growth via quartz cement in optical continuity). Most K-feldspar grains are altered or weathered accompanied by iron oxide. A few tiny-small (0.06-0.23 mm, ϕ = +4.05 - +2.13) and medium (0.34-0.52 mm, ϕ = +1.55 - +0.95) thin edge-on muscovite flakes wedged between, and sometimes bent around, quartz and K-feldspar grains and some embedded in or against quartz grains, some at an angle to the bedding. One longer (0.34 mm, ϕ = +1.55) edge-on muscovite flake is expanded due to alteration and with frayed ends is also at angle to the bedding. There are several small-medium (0.28-0.33 mm, ϕ = +1..85 - +1.60) and large (0.52-0.58 mm, ϕ = +0.95 - +0.78) sub-rounded altered (with iron-oxide staining) rock fragments with attached quartz overgrowths/cement. Iron oxide lines numerous grains and some small iron oxide patches occur between grains and infilling possible very small pores. But porosity is minimal and variable, averaging overall ~1.5%. There is some blue dye staining between and sometimes partially covering some grains due to the forced impregnation prior to the thin section being cut.

CCF-05 N 36° 09.258' W 111° 49.789' (N 36.154° W 111.830°)

8 m (26 feet) from CCF-04. Bed thickness 9 cm (3.5 inches). Dip (structural)—flat Strike—flat.

At normal scale, the thin section shows a massive, non-laminated, poorly sorted sandstone with quartz grains of various sizes, the coarser grains scattered between the randomly distributed medium and fine grains. Occasional K-feldspar grains evenly scattered through the rock fabric indicate this is a submature or arkosic quartz sandstone.

Under the microscope, a tightly packed and interlocking mosaic of quartz grains of various sizes [small (0.06-0.24 mm, ϕ = +4.05 - +2.06, coarse silt to fine sand size), medium (0.27-0.50 mm, ϕ = +1.90 - +1.00, medium sand size) and large (0.53-1.36 mm, ϕ = +0.92 - -0.44, coarse to very coarse sand size), all sizes together or in groups of similar size] and various shapes (sub-rounded to sub-angular to sub-euhedral) with sub-grains exhibiting different extinction angles, the grains frequently meeting at tight triple points, often due to overgrowths/cement usually in optical continuity. Edges/shapes are frequently irregular, likely due to resorption(?) of silica to provide the quartz cement. The mosaic is often molded around larger grains due to the cementation which produced the

tight fit of grains. Sometimes the medium-large quartz grains are elongated parallel to the bedding, some grains having “ghost” outlines of the original detrital grain with overgrowths in optical continuity. Many of the quartz grains (large-small) have specks and lines of iron oxide or are even “pitted” from their detrital origin, sometimes marking the original rounded shapes (“ghost” outlines), but now have overgrowths in optical continuity. Some grains exhibit undulose extinction. Sometimes the mosaic consists of both small angular to sub-rounded quartz and K-feldspar grains tightly packed with iron oxide filling inter-grain spaces and “molded” around large, rounded quartz grains often meeting at triple points, some in optical continuity with the central large grains as overgrowths/cement. Sometimes many large and medium quartz grains are fractured(?) into sub-grains but usually with optical continuity with one another and with the surrounding tight mosaic. Quite numerous small (0.04-0.23 mm, ϕ = +4.64 - +2.13, coarse silt to fine sand size), medium (0.26-0.50 mm, ϕ = +1.95 - +1.00, medium sand size) and large (0.52-0.69 mm, ϕ +0.95 - +0.54, coarse sand size) angular to sub-rounded or even partially euhedral K-feldspar grains and fragments (sometimes exhibiting remnant cross-hatched twinning under crossed polars) wedged in the mosaic of quartz grains. Several of the large rounded or sub-angular (sometimes broken or cracked along cleavage planes filled with iron oxide) or tabular (sub-euhedral) K-feldspar grains (sometimes exhibiting remnant cross-hatched twinning under crossed polars) wedged in the mosaic which sometimes has other small sub-rounded to sub-angular K-feldspar grains and angular fragments with the quartz grains. Most K-feldspar grains are altered (some highly altered) with some iron oxide staining and around edges. Quite a few large rounded and sometimes elongated, or smaller angular or rounded plagioclase grains or fragments, variably altered to clay(?) minerals and iron oxide and exhibiting remnants of definite or possible characteristic multiple twining surrounded by the “molded” mosaic. Numerous very small, small, medium and long (0.09-1.30 mm, ϕ = +3.47 - 0.37) thin edge-on muscovite flakes, some thick and fresh, some with pronounced bends and/or frayed and split-apart ends, wedged tightly at different angles between and bent around quartz and sometimes K-feldspar grains. Several very small (0.04-0.05 mm, ϕ = +4.64 - +4.23) edge-on fresh muscovite flakes and very small (0.03-0.05 mm, ϕ = +5.01 - +4.23) K-feldspar grains included in quartz grains. Several small-medium (0.10-0.50 mm, ϕ = +3.32 - +1.00, very fine to medium sand size) rounded very altered rock(?) fragments with partially resorbed diffuse edges. A very small (0.15 mm) thin, tabular, iron oxide stained, high relief, high birefringent grain is zircon. Iron oxide and sometimes alteration (clay? minerals) fill small pores adding to the cement, but usually there are no pores or small tight pore spaces, so the porosity varies, averaging overall ~5%. There is also some blue dye staining between and sometimes partially covering some grains due to the forced impregnation prior to the thin section being cut.

CCF-06 N 36° 09.256’ W 111° 49.784’ (N 36.154° W 111.830°)

5 m (~17.5 feet) from CCF-05. Bed thickness 6 cm (2.5 inches), cross-bedded unit here. Dip 40°W, strike 272° (bed structural measurements, not cross-beds).

At normal scale, the thin section shows the sandstone consists of bands/laminae of partially sorted grain sizes – fine, medium, coarse and very coarse quartz grains – though smaller grains occur among the medium and coarse grains. Occasional small and medium K-feldspar grains are scattered through these laminae indicate this is a submature or arkosic quartz sandstone.

Under the microscope, a tightly fitting and interlocking mosaic of quartz grains of various sizes [small (0.06-0.23 mm, ϕ = +4.05 - +2.13, coarse silt to fine sand size), medium (0.27-0.50 mm, ϕ = +1.90 - +1.00, medium sand size), large (0.52-0.98 mm, ϕ = +0.95 - +0.02, coarse sand size) and even very large (1.03-1.64 mm, ϕ = -0.04 - -0.71, very coarse sand size)], usually mixed together in various combinations) and shapes (euhedral to angular and sub-angular to sub-rounded and rounded) often with a mixture of straight, curved, irregular and diffuse edges (the latter two likely due to resorption? of silica to provide the quartz cement, or due to breakage) and sub-grains or internal domains with irregular edges exhibiting different extinction angles, the grains and sub-grains often meeting at triple points. Many quartz grains have specks and lines of iron oxide (some are rounded or sub-euhedral or have “broken” ends and are really “dirty”) or are even “pitted” from their detrital origin, rounded “ghost” outlines marking the original detrital grains and usually with euhedral overgrowths in optical continuity grown into what were pore spaces. One large, rounded quartz grain elongated parallel to the bedding consists of many small approximately-equal irregular sub-grains with different extinction angles, giving it a “sugary” texture like perhaps a quartzite (metamorphic) rock fragment. Some grains exhibit undulose extinction. In some areas the mosaic consists only of large overgrown quartz grains, whereas sometimes the mosaic consists of both small angular-subrounded quartz and K-feldspar grains tightly packed with iron oxide filling inter-grain spaces and “molded” around the large or very large rounded quartz grains often meeting at triple points, some in optical

continuity with the central large grains as overgrowths/cement. Many small (0.03-0.22 mm, ϕ = +5.01 - +2.19, medium silt to fine sand size) and medium (0.28-0.48 mm, ϕ = +1.85 - +1.06, medium sand size) euhedral or angular to rounded K-feldspar grains or fragments (often altered, some heavily and with iron oxide), and edges and cleavage planes lined by iron oxide within the mosaic of quartz grains. Several large (0.61-0.70 mm, ϕ = +0.70 - +0.52, coarse sand size) sub-rounded tabular/elongated K-feldspar grains, two relatively fresh with twinning in crossed polars, one partially broken with iron oxide along cleavage planes and fractures, and two large rounded heavily altered (with iron oxide) K-feldspar grains, all with the mosaic of quartz grains "molded" around them due to overgrowths/cement. Several small (0.07-0.19 mm ϕ = +3.77 - +2.40) and medium (0.45-0.50 mm ϕ = +1.15 - +1.00) rounded plagioclase grains exhibiting multiple twinning under crossed polars, some surrounded by iron oxide "cement." Many small (0.07-0.25 mm ϕ = +3.77 - +2.00), medium (0.30-0.41 mm ϕ = +1.75 - +1.29) and large or long (0.52-0.76 mm ϕ = +0.95 - +0.40) edge-on muscovite flakes, or even pairs of offset splayed flakes, occasionally thick and sometimes bent, or even very bent around other grains, but often with flayed sheets and frayed ends wedged along and between quartz grains at different angles, and several small (0.12 mm ϕ = +3.06) edge-on and a very small (0.03 mm ϕ = +5.01) face-on muscovite flakes included in a quartz grain, while another quartz grain has a very small (0.09 mm ϕ = +3.47) K-feldspar grain included in it. One medium-large quartz grain contains several very small (0.03 mm ϕ = +5.01) rounded inclusions of a high relief higher birefringence mineral, possibly zircon. Several small (0.09-0.16 mm ϕ = +3.47 - +2.66) and large (0.47-0.70 mm ϕ = +1.09 - +0.52) rounded grains "dirty" with iron oxide that may be rock fragments (or sometimes quartz) with "molded" mosaic around them including quartz cement attached to them like overgrowths in apparent optical continuity. One large area of calcite(?) cement(?) infilling a pore with iron oxide. Iron oxide lines many grains, and numerous small iron oxide patches occur between grains all through the thin section. Iron oxide and sometimes alteration (clay? minerals) fill small pores adding to the cement. There are some trivial to small pores, but often no pores, or small tight pore spaces, so the porosity varies, averaging overall ~2%. There is also some blue dye staining between and sometimes partially covering some grains due to the forced impregnation prior to the thin section being cut.

CCF-07 N 36° 09.260' W 111° 49.782' (N 36.154° W 111.830°)

4 m (13 feet) from CCF-06. Bed thickness 13 cm (5 inches). Dip 5°NE, strike 150° (difficult to make these structural measurements).

At normal scale, the thin section shows the sandstone fabric consists of cross-laminae at a low angle to the bedding that are mostly dominated by coarse and very coarse quartz grains with medium and fine

quartz grains scattered in between them, along with occasional K-feldspar grains, making this a partially sorted, submature or arkosic quartz sandstone.

Under the microscope, a tightly fitting and interlocking mosaic of quartz grains (euhedral, sub-euhedral and sub-angular to sub-rounded and rounded) various sizes [small (0.04-0.23 mm, ϕ = +4.64 - +2.13, coarse silt to fine sand size), medium (0.27-0.50 mm, ϕ = +1.90 - +1.00, medium sand size), large (0.52-0.94 mm, ϕ = +0.95 - +0.09, coarse sand size), and very large (1.06-1.77 mm, ϕ = -0.08 - -0.82, very coarse sand size)], often with euhedral overgrowths meeting at triple points in optical continuity surrounding the original rounded detrital grains which are "ghost" outlined by iron oxide lines and specks. Grain edges are straight, curved or irregular, sometimes embayed or diffuse, possibly due to resorption to provide the silica cement. Some grains are cracked and some exhibit undulose extinction. Often the larger quartz grains in the mosaic are filled in between by small irregular quartz grains, perhaps cement sometimes accompanied by iron oxide filling original pores. Many quartz grains have specks and lines of iron oxide or are even "pitted" from their detrital origin, with "ghost" outlines marking the original detrital grains. Some larger grains have irregular sub-grains with different extinction angles, while several large rounded quartz grains consist of many small approximately-equal, irregular sub-grains with different extinction angles, giving them a "sugary" texture like perhaps quartzite (metamorphic rock) fragments, yet part of one has a quartz overgrowth/cement attached to it, probably filling in an original pore, and meeting three adjoining grains at two triple points. Another large, rounded quartz grain has subtle radial fractures. Numerous small (0.06-0.22 mm, ϕ = =4.05 - +2.19, coarse silt to fine sand size), medium (0.26-0.50 mm, ϕ = +1.95 - +1.00, medium sand size) and large (0.53-0.83 mm, ϕ = +0.92 - +0.27, coarse sand size), angular and rounded K-feldspar fragments or grains, some partially broken, some fresh but many heavily altered with iron oxide staining, within "molded" mosaic. Many medium and large tabular with sub-rounded corners or rounded K-feldspar grains, some with iron oxide in cracks or along cleavage planes and surrounding them, others heavily altered and iron oxide stained, but one also partially broken with fragments among the small angular quartz grains together with iron oxide in each instance in between larger quartz grains perhaps filling original pores. One large rounded twinned K-feldspar crystal heavily altered and covered

with iron oxide staining with the mosaic tightly "molded" around it. Two small (0.12-0.14 mm ϕ = +3.06 - +2.84) and two large (0.53-0.59 mm ϕ = +0.92 - +0.76) tabular or rounded plagioclase grains with multiple twinning under crossed polars. Numerous small (0.03-0.23 mm ϕ = +5.01 - +2.13), medium (0.26-0.38 mm ϕ = =1.95 - +1.39) and long (0.64-0.71 mm ϕ = +0.65 - +0.50) edge-on muscovite flakes at different angles, some with flayed edges and/or bent, wedged between quartz fragments or grains, some with irregular small quartz grains and iron oxide filling possible original pores between the broken or rounded ends of large quartz grains or other large quartz grains in the tightly fitted mosaic. One medium, slightly-curved, edge-on muscovite flake inclusion within a medium-large quartz grain, and one small face-on muscovite flake. Several small (0.10-0.20 mm ϕ = +3.32 - +2.33), medium (0.26-0.31 mm ϕ = +1.95 - +1.70) and large (0.43 mm ϕ = +1.22) rounded rock (schist?) fragments (altered with iron oxide staining). Iron oxide lines the edges of grains and forms small patches between grains. Some apparent pores are filled by iron oxide and alteration (clay? minerals), but generally there are few or no pores, so the porosity varies and averages overall ~3%. There is some blue dye staining between and sometimes partially covering some grains due to the forced impregnation prior to the thin section being cut.

CCF-08 N 36° 09.264' W 111° 49.780' (N 36.154° W 111.830°)

6 m (20 feet) from CCF-07. Bed thickness 9 cm (3.5 inches). Dip 4°SW, strike 240° (difficult to bed structural measurements to make).

At normal scale, the thin section shows a poorly-sorted, non-laminated quartz sandstone with numerous very coarse quartz grains randomly scattered through a mosaic of coarse, medium and fine quartz grains, and occasional K-feldspar grains, making this a submature or arkosic quartz sandstone. Under the microscope, a tightly fitting and interlocking (like a jigsaw puzzle fit) mosaic of quartz grains, small (0.10-0.21 mm, ϕ = +3.32 - +2.25, very fine to fine sand size), medium (0.28-0.50 mm, ϕ = +1.85 - +1.00, medium sand size) and large (0.53-1.59 mm, ϕ = +0.92 - -0.67, coarse and very coarse sand size) to very large (2.30-2.40 mm, ϕ = -1.20 - -1.26, small granules) (often in mixtures), rounded and sub-rounded to sub-angular, angular and euhedral edges (often juxtaposed), often speckled with (some heavily) and have streaks of iron oxide, sometimes "ghost"

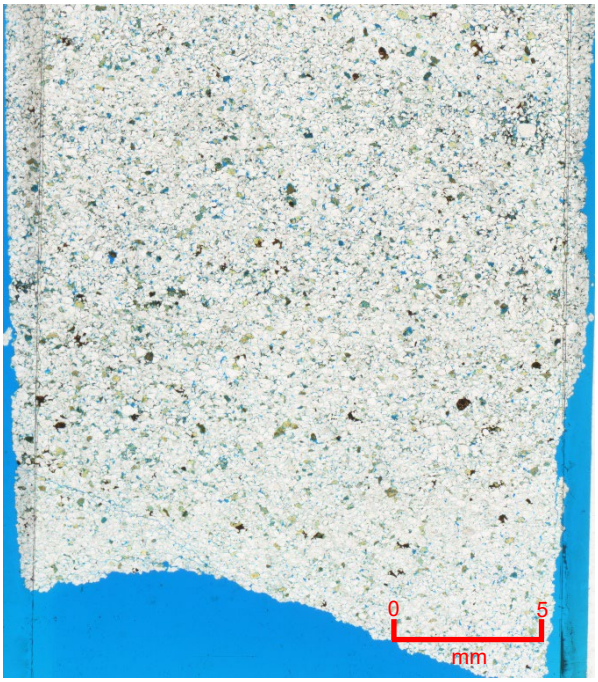
outlining the original detrital grains, but with overgrowths in optical continuity meeting at triple points to tightly cement the mosaic. Many grain edges are straight, but some are curved to fit into "jigsaw," while others are irregular or ragged, perhaps due to the resorption (?) which provided the quartz overgrowths/cement. Some large and medium quartz grains consist of patchworks of irregular sub-domains and sub-grains with different extinction angles. Often there are mixtures of grain sizes, with very large grains (2.30-2.40 mm, ϕ = -1.20 - -1.26) being surrounded by small or small-medium grains. Some grains exhibit undulose extinction some are cracked, probably from the forced impregnation. A very large, rounded quartz grain is embayed with two small-medium rounded quartz grains consisting of a patchwork of irregular sub-domains with different extinction angles (recrystallization?). There is also a patchwork of small sub-angular and sub-rounded quartz grains (with different extinction angles) with iron oxide and a small edge-on muscovite flake between them surrounded by the usual mosaic of larger quartz grains. Numerous medium (0.26-0.50 mm ϕ = +1.95 - +1.00) or large (0.53-0.79 mm ϕ = -0.92 - +0.35) tabular K-feldspar laths, grains or fragments, rounded or with rounded corners and/or broken ends, altered or heavily altered, and with iron oxide staining or just along cleavage planes and cracks, with mosaic "molded' around them, some K-feldspar grains even indented into neighboring quartz grains due to their overgrowths. Two small (0.08-0.21 mm ϕ = +3.64 - +2.25) K-feldspar fragments in mosaic of small interlocking quartz grains surrounded by medium-large interlocking quartz grains, and many other small and medium, altered K-feldspar rounded or angular fragments and laths, one broken in its middle and two (0.08-0.10 mm ϕ = +3.64 - +3.32) included in large quartz grains. Several medium (0.41-0.61 mm ϕ = +1.29 - +0.70), rounded and/or broken, altered portions of plagioclase laths with characteristic multiple twinning under crossed polars, and with mosaic "molded' around them. Several small (0.10-0.14 mm ϕ = +3.32 - +2.84), thin or thicker, some altered, edge-on muscovite flakes, sometimes bent, wedged between quartz grains, and a medium (0.23 mm ϕ = +2.13), thick edge-on muscovite flake at an angle included within and beyond the edge of a large quartz grain. A medium (0.39 mm ϕ = +1.36) elongated and rounded altered rock fragment with ends impinging on adjoining mosaic quartz grains, and small-medium (0.17-0.55 mm ϕ = +2.57 - +0.86) heavily altered rock fragments (?) within iron oxide filling a medium pore in the precise shape needed between euhedral ends of medium and large quartz grains (a later addition?). Similarly, iron oxide (plus clay alteration?) infilling medium and large pores in the precise shapes needed between euhedral ends of medium and large quartz grains (a later addition?). A former pore (?) surrounded by the ends of large euhedral quartz grains filled with tiny angular quartz grains (fragments?), broken (?) from some of those grain ends, but coated and between is blue dye staining from the forced impregnation, so that may have caused the disruption. Small and larger patches of iron oxide around and between some grains. Often there are no pores as the porosity varies, averaging overall

~2.5%. There is some blue dye staining between and sometimes partially covering some grains, and along cracks, due to the forced impregnation prior to the thin section being cut.

CCF-09 N 36° 09.279' W 111° 49.800' (N 36.155° W 111.830°)

Second bed sampled (lower, stratigraphically below first sampled bed). Distinct, small-scale cross-beds in unit. Bed thickness 7.5 cm (~3 inches), consistent between samples. No slickensides and no joints. This first sample above the hinge 1.5 m (5 feet) from sample CCF-10. Dip 76°E, strike 198° (tricky spot for bed structural measurements).

At normal scale, the thin section shows a non-laminated, partially sorted, finer-grained massive quartz sandstone with mostly medium and fine quartz grains in a mosaic with occasional scattered K-feldspar grains of similar sizes, making this a submature or arkosic quartz sandstone.



Under the microscope, a tightly fitting and interlocking mosaic of quartz grains and apparently broken fragments [consistently small (0.09-0.25 mm, ϕ = +3.47 - +2.00, very fine to fine sand size) and medium (0.26-0.48 mm, ϕ = +1.95 - +1.06, medium sand size), and occasionally medium-large (0.54-0.69 mm, ϕ = +0.89 - +0.54, coarse sand size)], sub-angular to sub-rounded and rounded, with straight or irregular edges and overgrowths meeting at triple points (probably infilling former pores) molded together to fit like a jigsaw puzzle, sometimes with intertonguing euhedral grain terminations. Sometimes the mosaic looks just like one solid mass of quartz, but still with grain boundaries evident. Grains are often speckled (some heavily making them look “dirty”) with and/or have streaks of iron oxide, sometimes “ghost” outlining the original, often rounded detrital grains, but with often clear overgrowths in optical continuity meeting at triple points to tightly cement the mosaic. Some grains consist of sub-grains with different extinction angles, some grain exhibit cracking, and some grains exhibit undulose extinction. Some irregular edges evidence probable resorption of silica to provide quartz cement. Two larger rounded quartz grains, one with an internal “ghost” outline and overgrowths, and the other exhibiting undulose extinction, are surrounded by regular molded tight-fit mosaic. An area of medium grains is somewhat elongated parallel to the bedding but still interlocked by overgrowths. One larger grain has an unusual concave curved edge, while another larger grain has some embayed edges with adjoining interlocking grains. Some larger elongated and rounded quartz grains have internal patchworks of irregular shaped and edged sub-domains with different extinctions and with the mosaic molded around them. Numerous small (0.09-0.25 mm, ϕ = +3.47 - +2.00) or medium (0.26-0.48 mm, ϕ = +1.95 - +1.06), and two larger (0.52-0.55 mm, ϕ = +0.95 - +0.86) K-feldspar grains, laths and fragments (sub-euhedral or angular with sub-rounded corners, or rounded and/or broken, altered or heavily altered with iron staining, sometimes heavily, one a former twinned crystal, two displaying cross-hatched twinning in crossed polars, several with adjoining K-feldspar fragments and/or with adjoining iron-oxide-stained alteration, in some cases possibly after K-feldspar?) surrounded by the molded mosaic. Five small-medium (0.21-0.33 mm, ϕ = +2.21 - +1.60) rounded possible plagioclase grains with multiple twinning under crossed polars. Several small (0.05-0.22 mm, ϕ = +4.23 - +2.19) thin, a thin and bent, and several thick (one expanded with frayed ends) edge-on muscovite flakes wedged between quartz grains at

angles. Two small (0.06-0.07 mm, ϕ = +4.05 - +3.77) edge-on muscovite flakes, each included within medium part-euhedral quartz grains. Two small (0.15-0.22 mm, ϕ = +2.75 - +2.19) rounded heavily altered rock fragment (schist?). Areas of tiny silica pieces and/or alteration (after K-feldspar?) and iron oxide filling in spaces shaped like former sub-euhedral quartz grains with straight edges (late alteration and infilling?). Minor iron oxide (possibly sometimes with alteration?) lining and between some grains, and former pores infilled with iron oxide, several around altered, rounded K-feldspar grains, sometimes with straight edges abutting sub-euhedral quartz grains or meeting quartz grains at triple points suggesting late infilling. Some apparent very small pores, but generally no pores, or occasional pores, the variable porosity averaging overall ~1.5%. There is also some blue dye staining between and sometimes partially covering some grains due to the forced impregnation prior to the thin section being cut.

CCF-10 N 36° 09.261' W 111° 49.797' (N 36.154° W 111.830°)

At the hinge of this fold. Bed thickness 7.5 cm (3 inches). Dip 52°E, strike 6° (bed structural measurements).

At normal scale, the thin section shows a non-laminated, partially sorted, finer-grained massive quartz sandstone with mostly medium and fine quartz grains in a mosaic with occasional scattered K-feldspar grains of similar sizes, making this a submature or arkosic quartz sandstone.

Under the microscope, a mosaic of tightly-fitted, interlocking quartz grains with different shapes (rounded and sub-rounded to sub-angular, angular, sub-euhedral and euhedral), and different sizes [small (0.10-0.21 mm, ϕ = +3.32 - +2.25, very fine to fine sand size) to mostly medium (0.26-0.50 mm, ϕ = +1.95 - +1.00, medium sand size), but also medium-large (0.52-0.64 mm, ϕ = +0.95 - +0.65, coarse sand size)], many with irregular and possibly resorbed edges, or even broken edges, often with iron oxide spots, speckling and streaks, and some with faint internal "ghost" outlines of the original detrital grains and often clear overgrowths in optical continuity, often meeting at triple points to produce a tight fit, as well as some irregularly-shaped sub-domains with different extinction angles, cemented by iron oxide (and sometimes some calcite) between some of the grains, sometimes appearing to be infillings of pores. Many rounded "dirty" detrital grains with clear

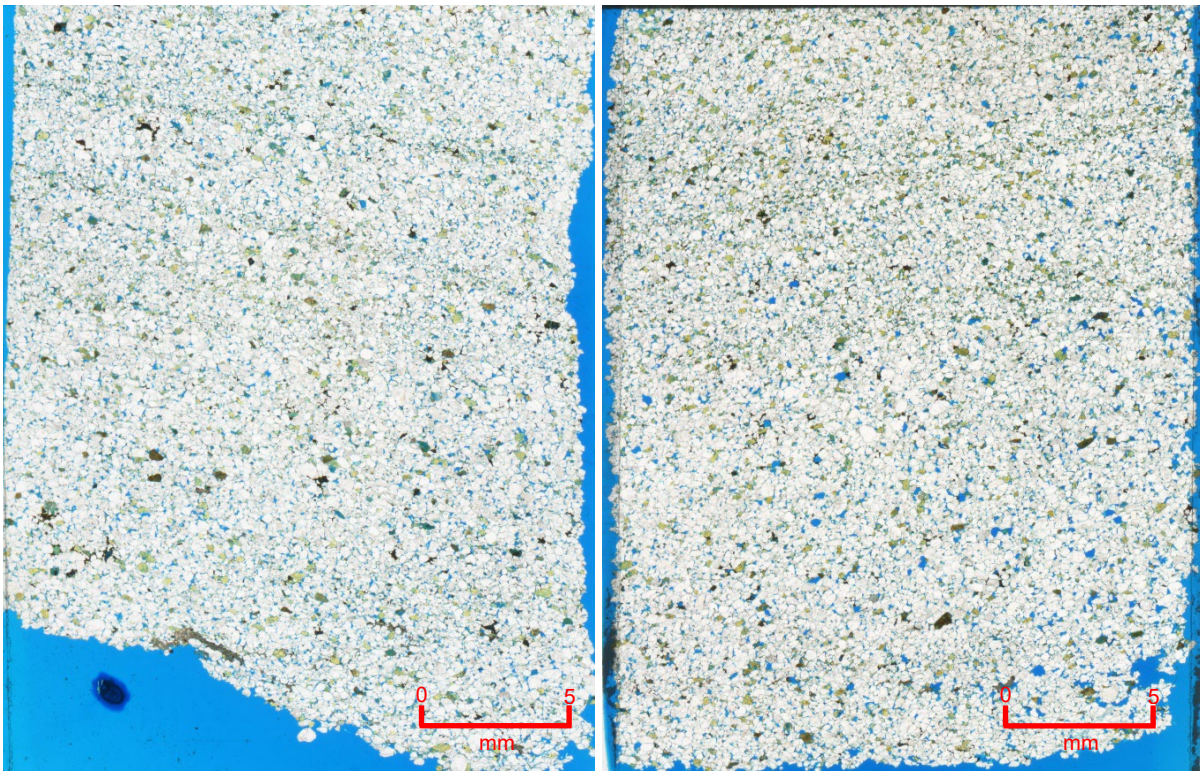
overgrowths cementing them to adjoining grains. Some grains have straight and/or rounded edges, some exhibit undulose extinction, and some elongated grains are mostly sub-euhedral. Some larger grains consist of sub-grains with different extinction angles, and some medium to large, rounded grains have patchworks of irregularly-shaped sub-domains with different extinction angles. A larger rounded quartz grain is surrounded by a huge (> ϕ = -1.63) mass of quartz molded around it with only subtle undulating grain boundaries meeting at triple points and grains with different extinction angles, all grains retaining their iron oxide spots and streaks, and apparent "stress" cracks. Very numerous medium (0.28-0.48 mm, ϕ = +1.85 - +1.06), some small (0.10-0.22 mm ϕ = =3.32 - +2.19) or medium-large (0.54-0.60 mm, ϕ = +0.89 - +0.74), rounded and/or broken K-feldspar laths, grains and fragments, mostly altered some heavily, some with iron oxide staining, some broken in situ and one split open with infilling calcite, some displaying cross-hatching in crossed polars, securely wedged within the surrounding mosaic sometimes with triple points, or lined with calcite and iron oxide between them and the surrounding mosaic. One K-feldspar grain abuts into a quartz grain, obviously due to the growth of the quartz cement around it, while another small (0.10 mm ϕ = +3.32) K-feldspar grain is included within a quartz grain. Three possible altered small-medium (0.19-0.33 mm, ϕ = +2.40 - +1.60) plagioclase laths with rounded corners displaying multiple twinning in crossed polars. A few small-long (0.09-0.34, mm ϕ = +3.47 - +1.55), thin (one expanded and thick) edge-on muscovite flakes, one with a bent end and two with frayed ends, wedged at angles between quartz grains. Four small and small-medium (0.20-0.47 mm, ϕ = +2.33 - +1.09), rounded and/or irregular heavily-altered rock fragments (schist and/or siltstone?). Many small-medium (0.17-0.34 mm, ϕ = =2.57 - +1.55) irregular calcite grains between mosaic grains, and a thick linear lining of calcite (with and without iron oxide) infills between medium and small euhedral, and medium irregular, quartz and K-feldspar grains, including meeting at triple points, as if the quartz grains were moved apart and the calcite then infilled between them. A medium-sized patch of calcite (coated with iron oxide) infills between two K-feldspar and several quartz grains. A linear area or band of very small-small calcite patches and small quartz grains, both with irregular edges with some iron oxide, and areas of calcite with iron oxide, and sometimes very small quartz fragments cemented together and possibly infilling pores or partially resorbed larger quartz grains. An area of iron oxide covered alteration with fuzzy edges adjoins a large K-feldspar lath with rounded corners. Occasional infilling patches of iron oxide between grains, and some possible very small pores, but the porosity varies and averages ~5%. There is some blue dye staining between and sometimes partially covering some grains due to the forced impregnation prior to the thin section being cut.

CCF-11 N 36° 09.258’ W 111° 49.794’ (N 36.154° W 111.830°)

2.3 m (7.5 feet) from the hinge of this fold (towards the river). Bed thickness 7.5 cm (3 inches). Strike 175°, dip 10° W (bed structural measurements).

At normal scale two thin sections show a non-laminated, partially sorted, finer-grained massive quartz sandstone with mostly medium and fine quartz grains in a mosaic with occasional scattered K-feldspar grains of similar sizes, making this a submature or arkosic quartz sandstone.

Under the microscope, a mosaic of tightly-fitted, interlocking quartz grains, and apparent angular fragments, with different shapes (irregular, sub-euhedral and sub-angular to sub-rounded and rounded) and different sizes [small (0.09-0.24 mm, ϕ = +3.47 - +2.06, very fine to fine sand size) to medium (0.29-0.50 mm, ϕ = +1.80 - +1.00, medium sand size), and medium-large (0.54-0.74 mm, ϕ = +0.89 - +0.44, coarse sand size), and sometimes elongated] with overgrowths/cement infilling to meet at triple points.



Many grains have irregular and rounded, resorbed edges, are at jumbled-appearing different orientations but still tightly-fitted “jigsaw,” and others have cracks and broken edges (not always due to forced impregnation?). Broken and rounded grains abut one another and small pieces of broken grains are adjacent. Sub-grains are common, and in medium and large grains are patchworks of irregular sub-domains of different sizes with different extinction angles. Some embayed large rounded and euhedral grains have other grains protruding into them. Iron oxide speckling and streaks, including around some edges, are common, and frequently there are “ghost” iron oxide outlines of detrital grain shapes and “dirty” grains with clear overgrowths/cement in optical continuity, with euhedral intertonguing tight fits

at triple points. Some larger elongated grains are parallel to the bedding, are irregular and rounded, but cemented with overgrowths tightly fitted at triple points. Some quartz grains exhibit undulose extinction. Some adjoining grains have complementing irregular or rounded edges, or angular "tongues," that interlock exactly, likely due to the quartz cement added to grain surfaces. Sometimes areas of many small grains are together (in one case both irregular-shaped quartz and K-feldspar grains/fragments) with peripheral medium-large grains, while other areas of medium and large grains interlocking tightly. Very numerous small (0.07-0.24 mm, ϕ = +3.77 - +2.06), medium (0.28-0.50 mm, ϕ = +1.85 - +1.00) and medium-large (0.53-0.67, mm ϕ = +0.92 - +0.58) (and elongated) rounded (though some are angular) K-feldspar laths, grains and fragments (some exhibiting cross-hatched twinning under crossed polars), are cracked, sometimes broken, sometimes with the fragments adjacent, and in one case the two halves wedged apart, and most are altered (some very heavily) often with iron oxide streaks along cracks and cleavage planes, are wedged within the surrounding mosaic sometimes with triple points, sometimes with adjoining iron oxide patches. One medium rounded possible altered K-feldspar grain has quartz overgrowths/cement attached to it, whereas one small (0.17 mm, ϕ = +2.57) rounded K-feldspar half-fragment is encased in a large rectangular quartz grain with rounded corners. Several small (0.18-0.22 mm, ϕ = +2.48 - +2.19) and medium (0.33-0.48 mm, ϕ = +1.60 - +1.06) rounded (and one broken with small pieces with iron oxide patches between them) altered plagioclase (?) grains exhibit multiple twinning under crossed polars. Many small or long (0.06-0.47 mm, ϕ = +4.05 - +1.09), thin or thick, edge-on muscovite flakes, many with bent and frayed ends, several degraded, all at various angles are wedged, and often bent to fit, between quartz and sometimes K-feldspar grains, and in two instances around or jutting into iron-oxide-filled former pores(?). Three small (0.07-0.12 mm, ϕ = +3.77 - +3.06) thin and thick, edge-on muscovite flakes are included within quartz grains. Four small-medium (0.10-0.38 mm, ϕ = +3.32 - +1.39) rounded heavily altered and iron-oxide-stained rock fragments (schist?), and a small (0.08 mm, ϕ = +3.64) high relief, high birefringent rounded tabular grain, probably zircon, are within the mosaic of quartz grains. Small, medium, large and very large areas of heavily iron-oxide-stained alteration are possibly clay minerals with tiny illite/muscovite flakes after multiple K-feldspar laths or fill former pores. Small patches of iron oxide are between some grains, some of which may be former pores, whereas there are some cracks and some small pores, the porosity varying but averaging overall ~4%. There is also some blue dye staining between and sometimes partially covering some grains due to the forced impregnation prior to the thin section being cut.

CCF-12 N 36° 09.258’ W 111° 49.792’ (N 36.154° W 111.830°)

Remote and around the corner ~40 m (~130 feet) from the major fold, down the slot canyon towards the river, but at the same stratigraphic level. A control sample in a similar thin sandstone bed between purple beds as in the main fold. These beds here are thin and wedge out to interfinger, so the within-bed boundaries are not due to faulting as claimed in identical situation in the main fold but are sedimentary structures.

At normal scale, the thin section shows a non-laminated, poorly sorted, quartz sandstone with large granule and very coarse sized grains scattered randomly and infilled between by mainly medium and fine grains. Occasional scattered small K-feldspar grains make this a submature or arkosic quartz sandstone. Under the microscope, a mosaic of tightly-fitted, interlocking quartz grains of different sizes [small (0.08-0.24 mm, ϕ = +3.64 - +2.06, very fine to fine sand size), medium (0.26-0.45 mm, ϕ = +1.95 - +1.15, medium sand size), large (0.51-1.00 mm, ϕ = +0.98 - 0.00, coarse sand size), very large (1.04-1.98 mm, ϕ = -0.06 - -0.98, very coarse sand size) and huge (2.14-2.50 mm, ϕ = -1.09 - -1.32, small granule size)], the

large and huge often surrounded by the other smaller grains, and different shapes (euhedral and sub-angular to rounded), sometimes with irregular edges due to resorption (?), and often with overgrowths infilling in optical continuity, making many of the grains euhedral to meet at triple points. But in the same fields of view there are irregular-shaped quartz grains with some sub-rounded corners and different extinction angles that are not so regular at meeting at perfect triple points, though still interlocking and tightly fitted. Often the original detrital grains are evident, some huge (2.14-2.50 mm, ϕ = -1.09 - -1.32) and rounded, as they are speckled with iron oxide streaks, sometimes concentric paralleling the rounded grain edges, and the overgrowths cementing them to adjacent grains are clear but in optical continuity. In many places the mosaic is so well overgrown/totally cemented in such a tight fit that the boundaries between the small-medium grains are faint and have almost disappeared to result in one apparent solid mass of quartz in optical continuity, but with faint or heavy streaks of iron oxide still outlining the original grain shapes that sometimes are also evident with different extinction angles in crossed polars. Some quartz grains exhibit undulose extinction. Many large, elongated irregular or rounded quartz grains consist of an irregular patchworks of irregularly-shaped sub-domains at different extinction angles but often meeting at triple points and some iron oxide staining their edges and are adjacent to other huge (2.14-2.50 mm, ϕ = -1.09 - -1.32) quartz grains and/or also small and medium grains, in one instance the sub-domains even extending to the other grains, even matching their extinction angles. Some very large-huge (1.04-2.50 mm, ϕ = -0.06 - -1.32) quartz grains have medium-large sub-grains. Very numerous small (0.05-0.24 mm, ϕ = +4.23 - +2.06) and medium (0.29-0.50 mm, ϕ = +1.80 - +1.00), sometimes a lot together, and occasional large (0.58-0.78, mm ϕ = +0.78 - +0.37) K-feldspar tabular laths and grains, altered (sometimes heavily altered with iron oxide staining, or with cleavage planes marked by iron oxide, or even displaying cross-hatched twinning under crossed polars) and with rounded corners, though sometimes still subangular or angular, are within the mosaic, and sometimes are so well cemented to the adjoining quartz grains that the K-feldspar grains appear embayed into them or embedded in the cemented mosaic. One medium angular heavily altered K-feldspar lath is included within a very large quartz grain. Many small or long (0.04-0.63 mm ϕ = +4.64 - +0.67), thin or thick, and sometimes degraded, edge-on muscovite flakes, sometimes bent and frayed at their ends, are

wedged at various angles between quartz grains. One long moderately thick edge-on muscovite flake has one broken end with a broken piece twisted back, and the other end bent and frayed, and is wedged tightly at an angle between mosaic quartz grains. Four small (0.06-0.14 mm, ϕ = +4.05 - +2.84, one thick) edge-on muscovite flakes are included within quartz grains, one small (0.22 mm, ϕ = +2.19) face-on muscovite flake is included in a huge quartz grain, and another three, small (0.03-0.12 mm, ϕ = +5.01 - +3.06) face-on muscovite flakes (one altered) are between quartz grains. A small (0.08 mm, ϕ = +3.64) high relief, high birefringent rounded grain is probably zircon, and a medium (0.41 mm, ϕ = +1.29) rounded dirty (iron oxide covered) rock grain was probably schist. Minor iron oxide coats grain edges and is in patches between grains. There are virtually no pores as cement has filled them, but there is some cracking and some small pores, with the porosity varying but overall averaging ~2%. There is also some blue dye staining between and sometimes partially covering some grains due to the forced impregnation prior to the thin section being cut.