GEOLOGICAL SOCIETY OF HONG KONG NEWSLETTER
Volume 22, No. 1, July 2016
Provenance of Seashore Sediments of the Wu Kai Sha Tsui, Hong Kong: A Petrographic Study of Sand Grains

The readers who are interested in discussing the content of the article please email to the Geological Society of Hong Kong at
geolsoc.hongkong@gmail.com

Editor: Ir. Raymond S M Chan

Provenance of Seashore Sediments of the Wu Kai Sha Tsui, Hong Kong: A Petrographic Study of Sand Grains

By Lin Hoi Yung and Wong Yiu Fai

Department of Civil and Environmental Engineering,
The Hong Kong Polytechnic University

Abstract

Eight sediment samples were collected along the seashore of Wu Kai Sha Tsui, Hong Kong. They were molded into thin sections for investigation of the mineral compositions and lithic fragments under a polarizing microscope. In addition, roundness and undulatory extinction were adopted to study the thin section samples. The main purpose for the study is to identify the source region of the sediment samples in the area. The test results of the samples are shown in detail in Table 1a and 1b. The high feldspar content generally infers that the depositional basin is close to the source of the sediments, and the depositional rate is relatively high. The test results for roundness exhibit that much higher percentages of the angular and subangular sand grains exist in comparison to the percentage of round and subrounded grains. These results also support the foregoing inference for a high depositional rate. The quartz content of the eight sediment samples is high, and therefore, the mineralogical maturity and stability of the study area is thought to be high. The high ratio of quartz to feldspar implies that the source region of the rock is granite, and the high ratio of K-feldspar to plagioclase also indicates that the source region of the sediments was exposed in a humid climate. By means of adopting the undulatory extinction method, it identifies that both the low-rank metamorphic and plutonic regions existed. Furthermore, the ternary diagrams of provenance analysis show that the sediments in Wu Kai Sha Tusi originated from sialic crust (i.e. continental block and recycled orogeny).

Introduction

Wu Kai Sha Tsui lies in the eastern part of New Territories, Hong Kong. It is located south and north of the Tolo Channel and Lok Wo Sha respectively. The Sha Tin Granite forms the bedrock geology in the area and yielded ages of 148 ± 9 Ma and 146 ± 0.2 Ma (Strange, 1990; Sewell et al, 1992; Davis et al, 1997). A further study by Campbell et al (1998) suggests that the Sha Tin Granite is one of the major constituents of the Kwai Chung Suite.

This study is focused on sediments along the seashore of Wu Kwai Sha Tsui and the beach of To Tau. The sediments are characterised by two fundamental properties: mineral composition and texture as adopted by Krynine (1948). The sand grains were sorted from the sediment samples, and they were molded into thin sections for both petrographic and textural analysis.

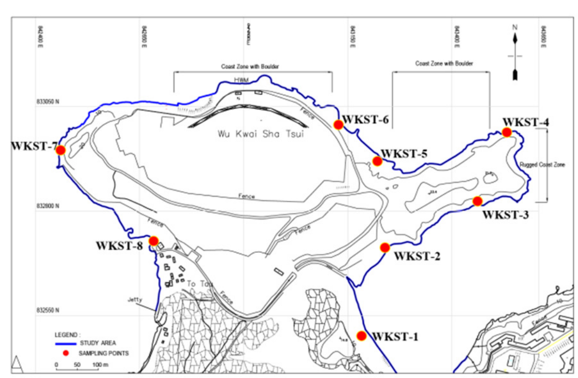

Figure 1: Map showing the locations of the samples (red dots).

Sampling Procedure

The eight sediment samples were collected from the locations shown in Figure 1. Each sample covered an area of 144 cm^2 (12 cm x 12 cm grid). In order to avoid contamination of the samples the top layer of 20mm thick sediments at each of the sampling locations was dug and removed before the collection. The mass of each sample was about 200g, and they were numbered from WKST-1 to WKS-8 respectively. The samples were dried in an oven overnight, and were subsequently sieved. The medium sand grains with diameters between 0.125mm and 0.5mm were isolated for thin section analysis.

Petrographic Analysis

Each of the eight thin sections were separated into twelve partitions, and each partition was further divided into nine grids. Therefore, there were totally one hundred and eight grids to be counted as points by the method adopted by Dickson (1970). Each of the mineral groups or lithic fragments was counted and identified within the grids using a petrographic microscope.

The mineral compositions of the sand particles are mainly quartz and feldspar. The quartz grains are divided into monocrystalline quartz grains and polycrystalline quartz grains (Dickson and Suczek, 1979) respectively. Most of the monocrystalline quartz grains are sourced from igneous rocks whereas the polycrystalline quartz grains are sourced from metamorphic rocks (Blatt, 1967). The grains are distinguished between mineral grains and lithic fragments respectively. Feldspar grains are further divided into plagioclase grains which have the polysynthetic twining, and the K-feldspar grains which exhibit tartan plaid twining. Except the polycrystalline quartz grain was sorted to lithic fragments, the sand particle also contained the lithic fragment from the sedimentary rock. In this study shell and skeletal fragments were neglected.

The percentage of quartz grains range from 55.8% to 72.9% (Table 1a; Column 2). The feldspar grains range from 20.8% to 32.6% (Column 3) and the lithic fragments range from 4% to 14.3% (Column 4). The percentage of monocrystalline quartz grains ranges from 43.2% to 61.2% (Column 6) and total lithic fragments range from 14.9% to 26.5% (Column 8). The polycrystalline quartz grains range from 41.2% to 73.3% (Column 10). Volcanic and metavolcanic lithic fragments were not observed (Column 11) otherwise the sedimentary and metasedimentary lithic fragments range from 26.7% to 58.8% (Column 12). The plagioclase grains range from 1.2% to 9.1% (Column 15), and the K-feldspar grains range from 16.9% to 40.3% (Column 16).

A similar study on sedimentary provenance by Wiesnet (1961) at Potsdam near New York found that the percentage of feldspar grains ranged from 10% to 25%. He then concluded that the sediments in the area were deposited quickly and they had not been reworked. It is because the feldspar grains had not been decomposed in the area. He believed that the sediments in the source region had not entirely undergone deep chemical weathering to decompose most of the feldspar grains or the source area was near to the depositional basin such that the feldspar grains in the sediments had not sufficient time to be decomposed. As the percentage of the feldspar grains in Wu Kai Sha Tsui ranges from 20.8% to 32.6% (Column 3), it is higher than of the results found by Wiesnet in Potsdam. Therefore, it is believed that the source region for the sediments in Wu Kai Sha Tsui should be near to the depositional basin, and the deposition rate was relatively high.

Provenance Type

Basu (1976) subdivided provenance into to four variables: relief, climate, source rock type, and source rock location. Dickinson and Suczek (1979) classified all provenance and derivative sandstone suites into three general groups: continental block, magmatic arc and recycled orogen. Continental block refers to a sedimentary source from a shield and platform terrane or from faulted basement block; magmatic arc refers to the source is within an active arc orogen of island arcs or active continental margins; recycled orogen refers to source is deformed and uplifted strata sequences in subduction zones along collision orogen or within foreland fold-thrust belts.

Framework Modes

The provenance analysis of sand from Wu Kai Sha Tusi is in accordance with the method from Dickinson and Suczek (1979). The point-counting results of the eight thin sections (Figure 2) were plotted into Q-F-L, Qm-F-Lt, Op-Lv-Ls and Qm-P-K ternary diagrams. Q refers to stable quartzose grains that include: monocrystalline quartz (Qm) and polycrystalline quartzose lithic fragments (Qp). F is the monocrystalline feldspar grains that include plagioclase (P) and K-feldspar grains (K). L is the unstable polycrystalline lithic fragments that include volcanic and metavolcanic types (Lv), sedimentary and metasedimentary types (Ls). Lt is the total lithic fragments that equal the sum of the unstable lithic fragments (L) and the stable quartzose lithic fragments (Qp).

The Q-F-L ternary diagram emphasizes the grain stability relative to weathering, provenance relief, transportation mechanism and source rock. Qm-F-Lt emphasizes the grain size of the source rocks (finer grained rocks yield more lithic fragments in range of sand grains). Qp-Lv-Ls and Qm-P-K reveal the characteristics of the polycrystalline and monocrystalline components of framework modes (Dickinson and Suczek, 1979).

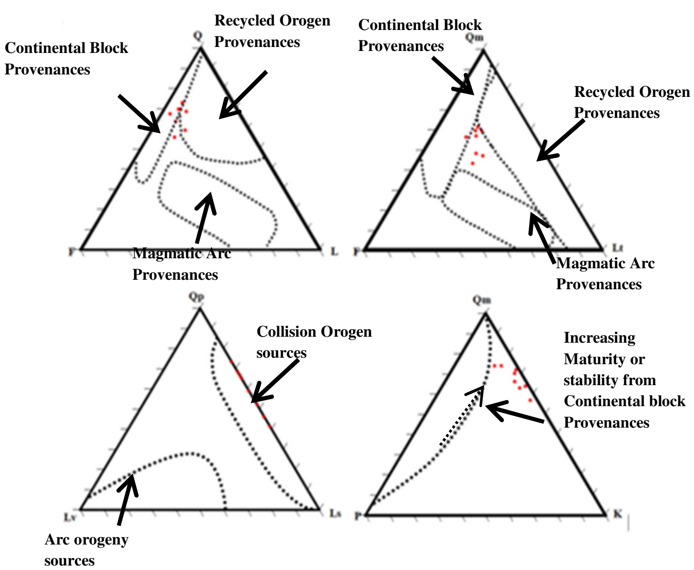

Figure 2: By means of adopting the provenance analysis method of Dickenson and Suczek (1979), the Q-F-L and Qm-F-Lt ternary diagrams imply that the sediment provenances of Wu Kai Sha Tsui was derived from a continental block and/or recycled orogen. The Qp-Lv-Ls ternary diagram indicates that the source region was from a collisional orogen. The Qm-P-K ternary diagram displays that the provenance was from a mature or stable continental block.

Provenance Analysis

From the point-counting results (Figure 2), the provenance of Wu Kai Sha Tsui is likely similar to sialic continental crust (i.e. continental block and/or recycled orogen).

The rock exposed at Wu Kai Sha Tsui (Figure 3) is the Sha Tin Granite (Strange, 1990), and it forms an irregular elliptical-shaped pluton centered in Sha Tin District with the long axis oriented to northeast (Sewell, 2000). It belongs to Cathaysia Block of the Eurasian Plate. The Sha Tin Granite consists of quartz, K-feldspar and plagioclase minerals. It is one of the source regions for the sand grains along the shoreline of Wu Kai Sha Tsui.

Figure 3: Rock outcrop of Sha Tin Granite in Wu Kai Sha Tsui.

Three Fathoms Coves is located at the south of Wu Kai Sha Tsui, and the exposed rock belongs to the Tolo Harbour Formation and Bluff Head Formation. They are composed of sedimentary rocks which include siltstone, mudstones, sandstone and conglomerate. Part of the lithic fragments of sediments is derived from the above mentioned formations.

Figure 4: Rock outcrop along the coastal area of Three Fathoms Coves.

Basu (1976) found that sand grains tend to plot closer to the apex of total quartz (Q) (c.f. Figure 2a) and is attributed to high mineral maturity. Further studies by Basu (1976) found that the quartz to feldspar ratio of a granitic pluton is typically between 0.2 and 0.6. Dickinson (1970) also indicated that the Q apex in the plot of Q-F-L represents greatest stability. The quartz to feldspar ratio (Figure 5) of the sand grains in Wu Kai Sha Tsui range from 1.17 to 3.50 (Column 17) and is much higher than that of the results reported by Basu (1976), therefore the source of sediment is not mainly from the granitic pluton.

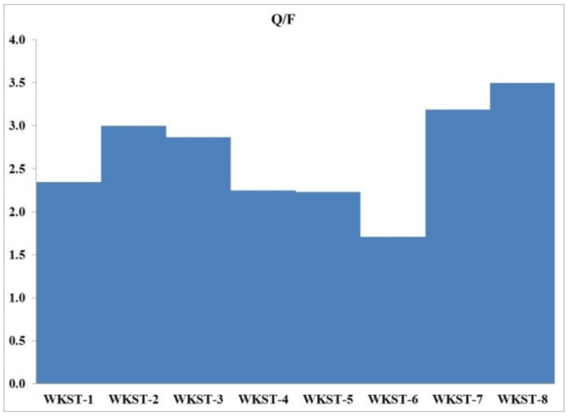

Figure 5: Histogram for the ratios of the quartz grains to the feldspar grains.

Basu (1976) found that the ratio of the K-feldspar to plagioclase is < 1 for rocks in humid climates. The ratio of the K-feldspar to plagioclase from Wu Kai Sha Tsui ranges between 1.9 and 25 (Column 18), and has an average ratio of 11.45. The histogram in Figure 6 shows that all the ratios of the two feldspar grains are > 1. Therefore the rock source climate region of the sand grains was likely one of high humidity.

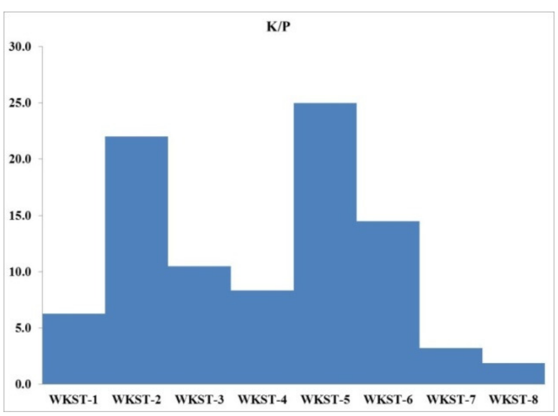

Figure 6: Histogram for the ratios of K-feldspar to plagioclase.

Roundness

The results of roundness for the grains are summarised in both Table 1b and Figure 7, and shown in Plates 1 to 3. The percentage of the angular shaped grains range from 67.7% to 79.6%; the sub-angular shaped grains range from 6.1% to 16.2%; the sub-rounded shaped grains range from 3.2% to 13.1% and the rounded grains range from 3.0% to 9.5%. Sample WKST-2 has a slightly lower percentage of angular grains (i.e. 67.7%) whereas the other samples are > 70%. The rounded particles of the eight sand samples are less than 10%. As the sediments are far away from their source region, the roundness of sediments increases (Selly, 1988). It indicates that the sand particles travelled a short distance before deposition (Powers, 1953). As most of the sand sediments in Wu Kai Sha Tsui are found to be angular to subangular shaped, it infers that the region source for the sediments is close to the depositional area.

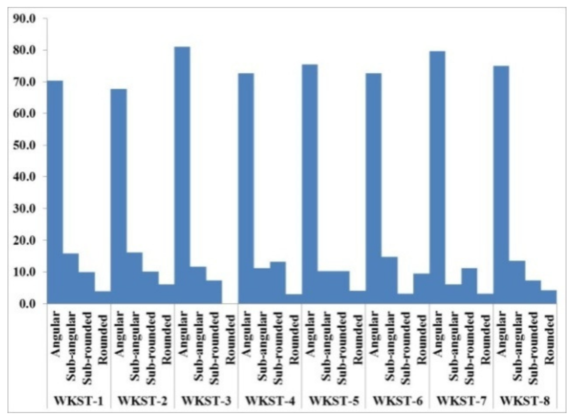

Figure 7: Histogram for roundness in sand grains

Undulatory Extinction

On occasion there was evidence that the rock had suffered strain, likely to be a consequence of the bending. Different parts of a single grain are in slightly different orientations and would go through extinction at different times under observation by polarizing microscope (Nesse, 1991). This sort of extinction is undulatory extinction (plate 2). Therefore, undulatory extinction would be the indicator of a strained event. Possess of undulatory indicate the low-rank metamorphic origin, and nonundulatory indicate plutonic origin (Basu. et. al, 1975). Undulatory extinction can be used to detect any of the strained events occurred. The test results for the sediment samples in Wu Kai Sha Tsui found that the percentage of undulatory extinction ranges from 4.1% to 68.5%, and the percentage of non-undulatory extinction ranges from 31.5% to 95.9%. The comparatively high percentage of undulatory extinction in WKST-3 (i.e., 68.5%) infers that the strained event occurred in this area. According to the geological investigation conducted by Lee (1990), a fault was discovered and mapped close to the location of sample WKST-3. The fault was verified by Lee (1990) to be related to the Sham Chung–Nai Chung fracture belt. The presence of the fault can reasonably explain the deformation of rock from the source area near the sample WKST-3. From the results of undulatory extinction, it implies that a minor portion of sand particles from the source region suffered from deformation in the low-rank metamorphism origin. Apart from the result of WKST-03, the majority of sand grains were likely sourced from a pluton origin.

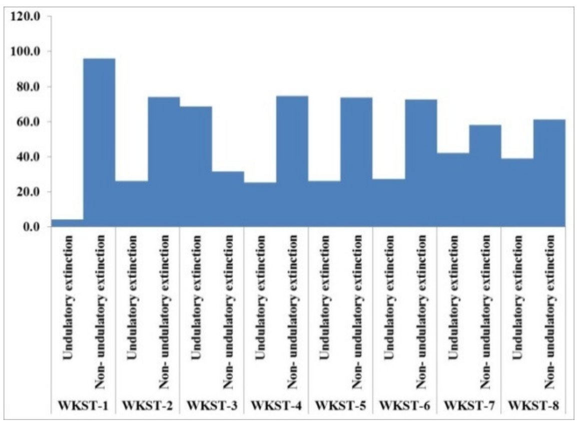

Figure 8: Histogram for undulatory extinction for sand grains

Conclusion

The content of feldspar in sand grains range from 20.8% to 32.6% in sediments infers that the depositional basin was close to the source of the sediments, and the deposition rate was relatively high. The roundness analysis indicates that a major portion of the sediments had a short transportation distance from the source region and they were near to their depositional area. The quartz content in sand grains ranges from 55.8% to 72.9% and indicates the mineralogical maturity and stability condition of the sediments in the study area are high and great. Ratio of quartz and feldspar (1.7-3.5) implicate rock of the source region is not only granitic pluton. Furthermore, the ratio of K-feldspar to plagioclase ranges from 1.9 to 25.0 which indicates that the source region was located in a humid climatic area. The undulatory extinction provides a hint to discriminate the low-rank metamorphic region from the plutonic region. The undulatory extinction for the grains ranges from 4.1% to 68.5% and nonundulatory extinction ranges from 31.5% to 95.9%. It implies that the two types of source regions existed. Lastly, the ternary diagrams of provenance analysis on the sand grains supports the provenances of Wu Kai Sha Tusi as sialic crust (i.e. continental block and recycled orogeny).

Reference

Adam, A. E., MacKenzie, W. S. & Guilford, C., 1997, Atlas of sedimentary rocks under the microscope, Addison Wesley Longman Limited.

Basu, A., Young, S. W., Suttner, L. J., James, W., C. and Mack, G. H., 1975, Re-evaluation of the use of undulatory extinction and polycrystallinity in detrital quartz for provenance interpretation, Jour. of Sedimentary Petrology, vol. 45, no.4, p.873-882.

Basu, A., 1976, Petrology of Holocene fluvial sand derived from plutonic source rocks: implications to paleoclimatic interpretation, Jour. of Sedimentary Petrology, vol. 46, no.3, and p.694-709.

Blatt, H., 1967, Provenance determinations and recycling of sediments, Jour. Of Sedimentary Petrology, vol. 37, no.4, p.1031-1044.

Campbell, S. D. G. and Sewell, R. J., 1998, A proposed revision of the Volcanic stratigraphy and related Plutonic classification of Hong Kong, Hong Kong Geologist, vol. 4, p.1-11.

Davis, D. W., Sewell, R. J. & Campbell, S. D. G., 1997, U-Pb dating of Mesozoic igneous rocks from Hong Kong, Journal of the Geological Society, London, vol. 154, p. 1067-1076.

Dickinson, W. R., 1970, Interpreting detrital modes of greywacke and arkose, Journal of Sedimentary petrology, v. 40, p. 695-707.

Dickinson, W. R. and Suczek C. A., 1979, Plate Tectonics and Sandstone Compositions, The American Association of Petroleum Geologists Bulletin, v. 63, no.12, p.2164-2182.

Krynine, P. D., 1948, The megascopic study and field classification of sedimentary rocks, Jour. Geology, vol.56, p130-165.

Lee, C. M., 1990, The Tectonic Framework of Hong Kong and Vicinity and its relationship of Regional Seismicity, M. Phi. Thesis, University of Hong Kong, 455p.

Nesse, W. D., 1991, Introduction to Optical Mineralogy, second edition, Oxford University Press.

Powers, M. C., 1953, A new roundness scale for sedimentary particles, vol. 23, no. 2, p. 117-119.

Selly, R. C., 1988, Applied Sedimentology, Academic Press, 446p.

Sewell, R. J., Darbyshire, D. P. F., Langford, R. L. & Strange, P. J., 1992, Geochemistry and Rb-Sr geochronology of Mesozoic granites from Hong Kong. Transactions of the Royal Society of Edinburgh: Earth Sciences, vol. 83, p. 269-280.

Sewell, R.J., Campbell, S. D. G., Fletcher, C. J. N., Lai, K. W. and Kirk, P. A., 2000, The pre-quaternary geology of Hong Kong, Geotechnical Engineering Office, Civil Engineering Department, The Government of the Hong Kong.

Strange, P. J., 1990, The classification of granitic rocks in Hong Kong and their sequence in the emplacement in Sha Tin, Kowloon and Hong Kong, Geological Society of Hong Kong Newsletter, vol. 8, p. 18-27.

Wiesnet, D, R., 1961, Composition, grain size, roundness and sphericity of The Potsdam sandstone (Cambrian) in Northeastern New York, jour. of Sedimentary Petrology, vol.31, no.1, p.5-14.

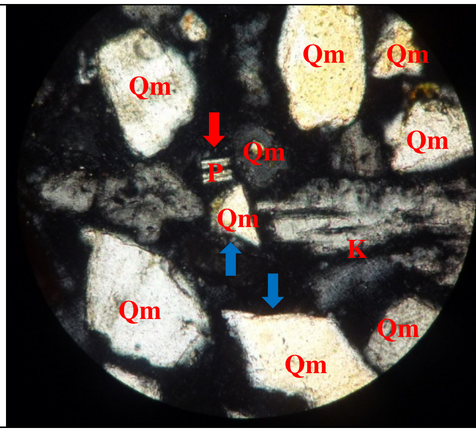

Plate 1a: Angular plagioclase grain (red arrow) and monocrystalline quartz grains (blue arrow). The roundness of the other grains are from subangular to subrounded. Qm: Monocrystalline quartz grains, P: plagioclase grains, K: K-feldspar grains. The length of photo is 1mm.

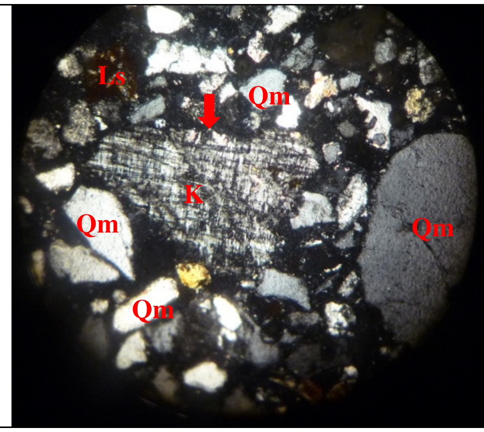

Plate 1d: Microcline with tartan plaid (cross hatched) twining (red arrow). Qm: Monocrystalline quartz grains, K: K-feldspar grains, Ls: sedimentary lithic fragment. The length of photo is 2 mm.

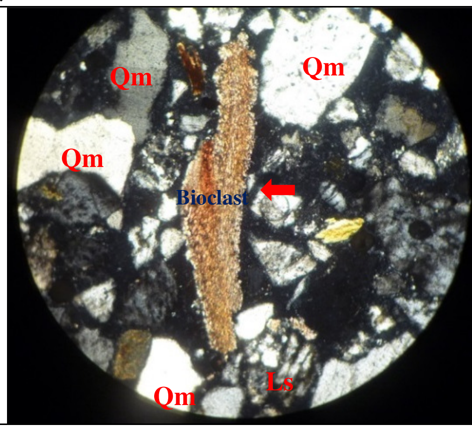

Plate 1b: The elongated bioclast grain is shell fragment (red arrow). Qm: Monocrystalline quartz grains, Ls: sedimentary lithic fragment, Bioclast: Skeletal particle. The length of photo is 2 mm.

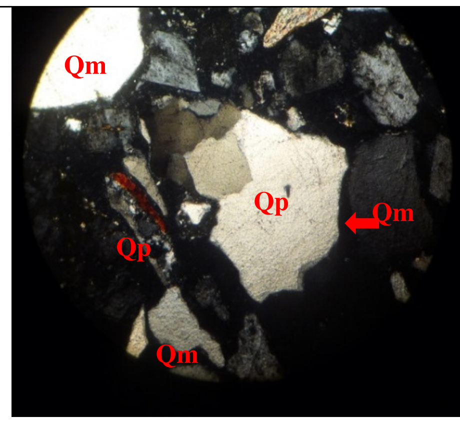

Plate 1e: Polycrystalline quartz grains (red arrow) are made up of a number of quartz crystals in different orientations. Qm: monocrystalline quartz, Qp: polycrystalline quartz grains. The length of photo is 2 mm.

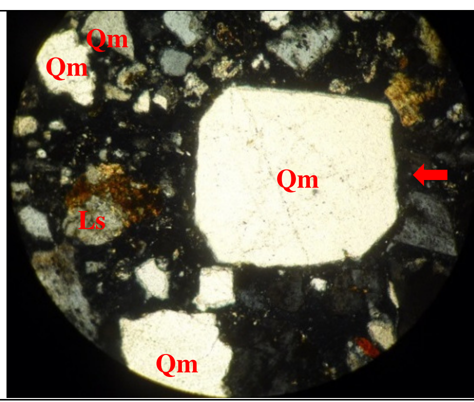

Plate 1c: Monocrystalline quartz grains (red arrow) is a single crystal of quartz grain. Qm: Monocrystalline quartz grains, Ls: Sedimentary lithic fragment. The length of photo is 2 mm.

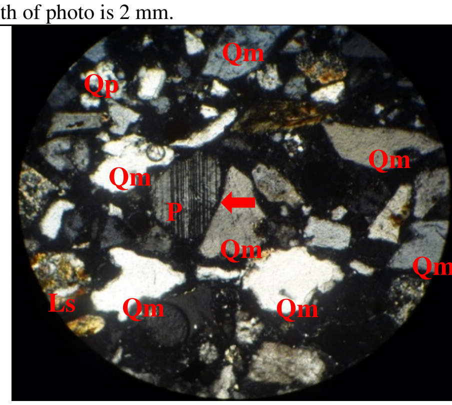

Plate 1f: Polysynthetic twinning is characteristic of plagioclase (red arrow). Qm: monocrystalline quartz, Qp: polycrystalline quartz, Ls: sedimentary lithic fragment. The length of photo is 2 mm.

Plate 1

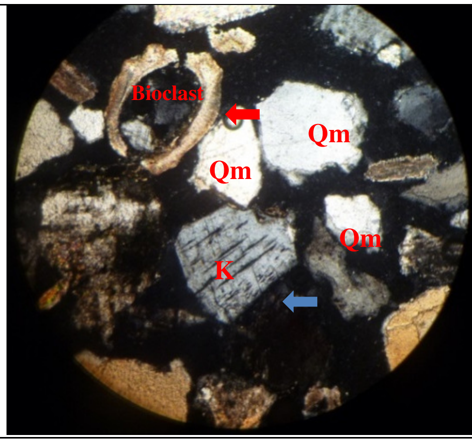

Plate 2a: Some bioclast is two-valved shell (red arrow). Inside the shell have few quartz grains. The Feldspar was indicated by blue arrow have two direction cleavages. Qm: monocrystalline quartz, K: K-feldspar, Bioclast: skeletal particle. The length of photo is 2 mm.

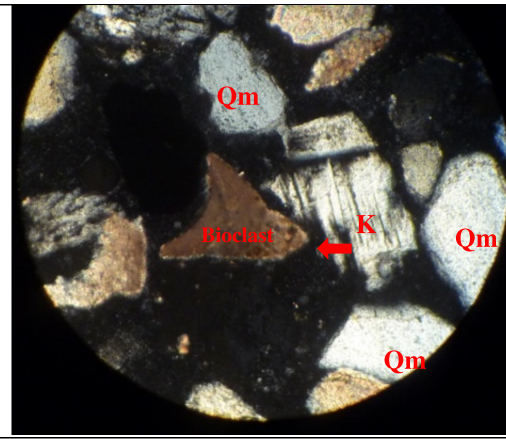

Plate 2d: A shark tooth (red arrow) was found in WKST-4. Qm: monocrystalline quartz, K: K-feldspar, Bioclast: skeletal particle. The length of photo is 2 mm.

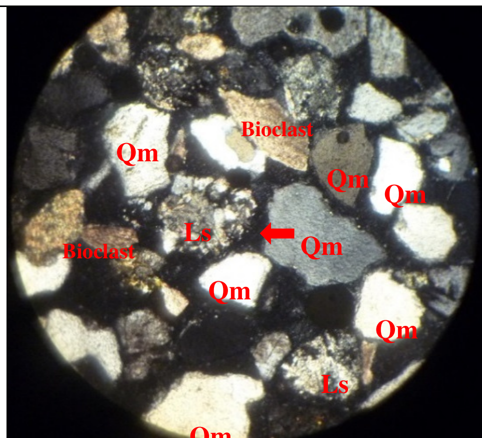

Plate 2b: Angular sandstone lithic fragment (red arrow). Qm: monocrystalline quartz, Ls: sedimentary lithic fragment, Bioclast: skeletal particle. The length of photo is 2 mm.

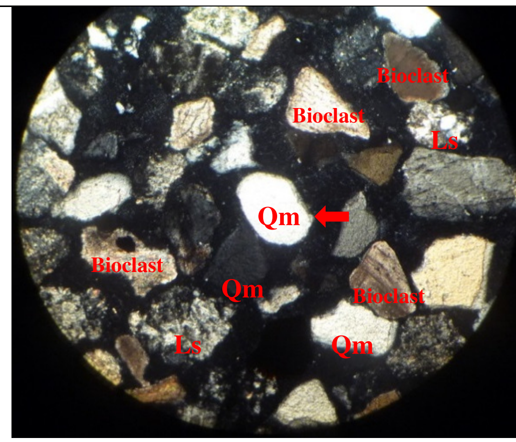

Plate 2e: Rounded shape monocrystalline quartz (red arrow). Qm: monocrystalline quartz, Ls: sedimentary lithic fragment, Bioclast: skeletal particle. The length of photo is 2 mm.

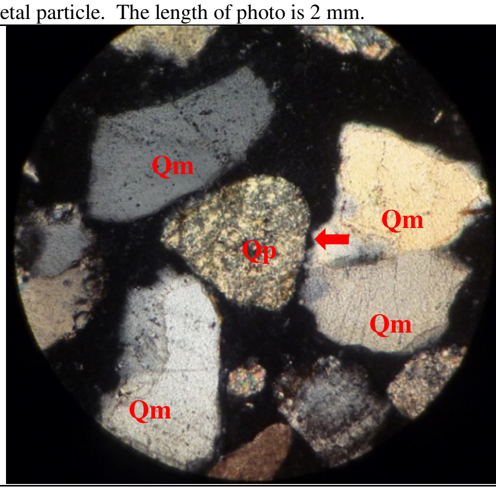

Plate 2c: Some of the polycrystalline is chert (red arrow). Qm: monocrystalline quartz, Qp: polycrystalline quartz. The length of photo is 1 mm.

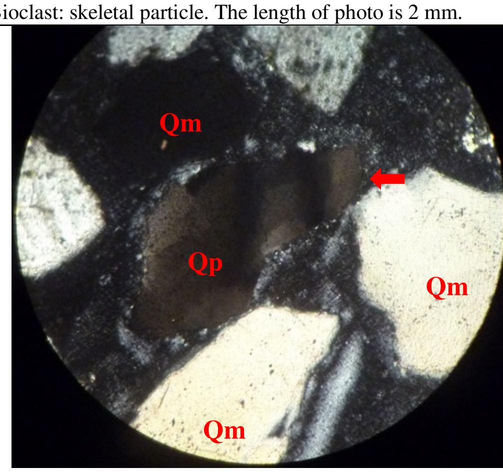

Plate 2f: Undulatory polycrystalline quartz (red arrow) with monocrystalline quartz. Qm: monocrystalline quartz, Qp: polycrystalline quartz. The length of photo is 1 mm.

Plate 2

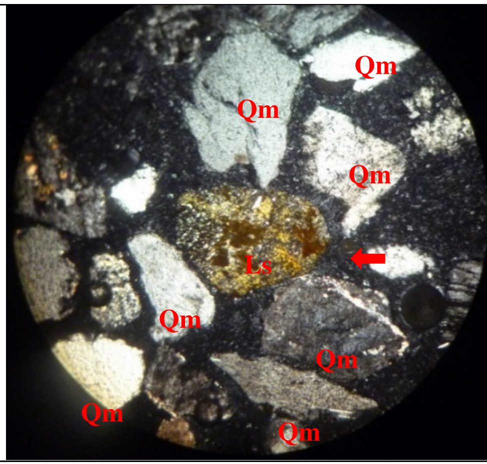

Plate 3a: Rounded siltstone lithic fragment (red arrow). Qm: monocrystalline quartz, Ls: sedimentary lithic fragment. The length of photo is 2 mm.

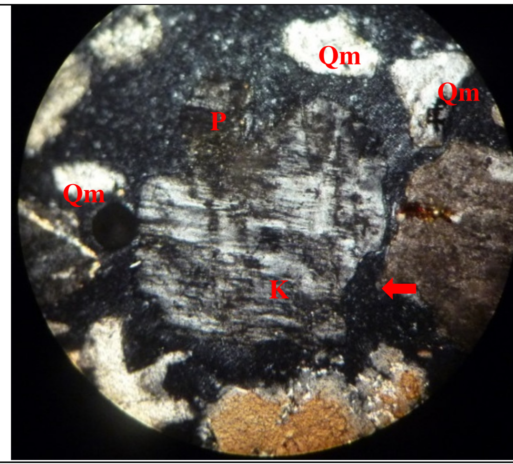

Plate 3d: Subrounded shape microcline with tartan plaid (cross hatched) twining (red arrow). Qm: monocrystalline quartz, P: plagioclase, K: K-feldspar. The length of photo is 2 mm.

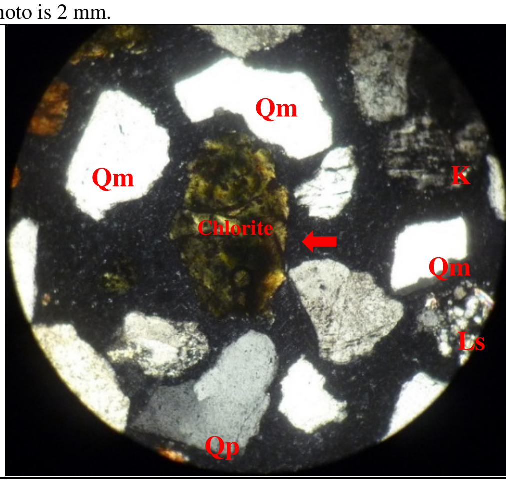

Plate 3b: Chlorite (red arrow) was found in the WKST-6. Qm: monocrystalline quartz, Qp: polycrystalline quartz, K: K-feldspar, Ls: sedimentary lithic fragment. The length of photo is 2 mm.

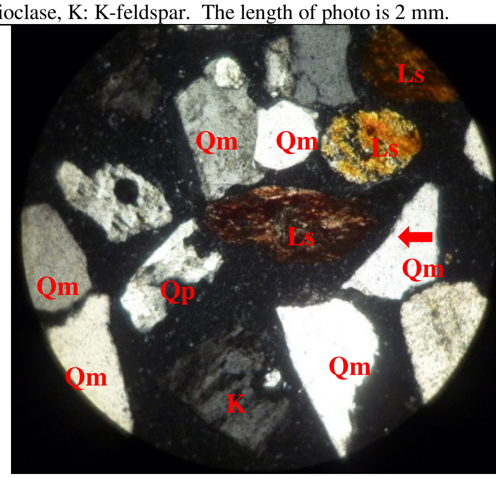

Plate 3e: Rounded shale lithic fragment (red arrow). Qm: monocrystalline quartz, Qp: polycrystalline quartz, K: K-feldspar, Ls: sedimentary lithic fragment. The length of photo is 2 mm.

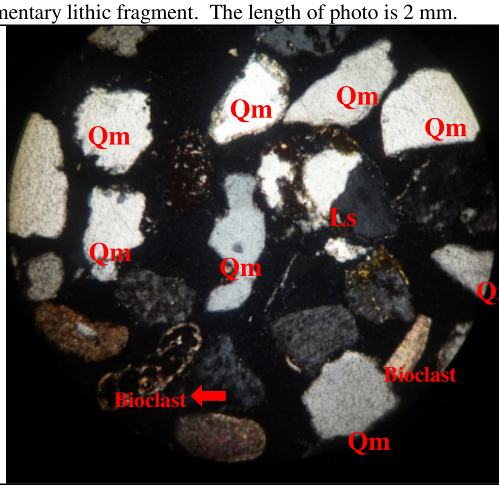

Plate 3c: Angular shape monocrystalline and one of bioclast is benthic foraminifera (red arrow). Qm: monocrystalline quartz, Ls: sedimentary lithic fragment, Bioclast: skeletal particle. The length of photo is 2 mm.

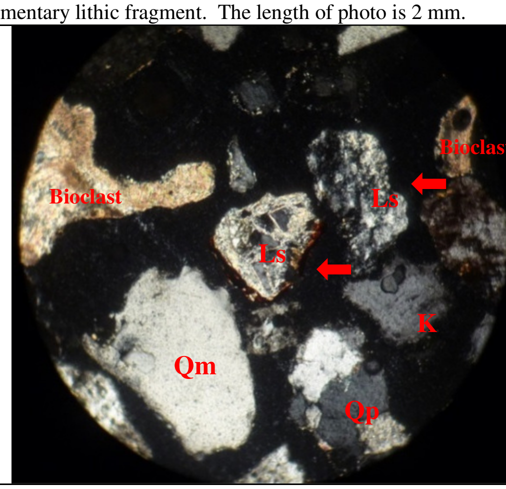

Plate 3f: Subangular sandstone lithic fragment (red arrow). Qm: monocrystalline quartz, Qp: polycrystalline quartz, K: K-feldspar, Ls: sedimentary lithic fragment, Bioclast: skeletal particle. The length of photo is 2 mm.

Plate 3

Column No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Sample No.	Total Points Counted (QFL)	Q%	F%	L%	Total Points Counted (QmF Lt)	Qm%	F%	Lt%	Total Points Counted (QpLvLs)	Qp%	Lv%	Ls%	Total Points Counted (QmPK)	Qm%	P%	K%	Q/F	K/P
WKST-1	101	67.3	28.7	4.0	101	56.4	28.7	14.9	15	73.3	0	26.7	86	66.3	4.7	29.1	2.3	6.3
WKST-2	99	69.7	23.2	7.1	99	59.6	23.2	17.2	17	58.8	0	41.2	82	72.0	1.2	26.8	3.0	22.0
WKST-3	95	69.5	24.2	6.3	95	56.8	24.2	18.9	18	66.7	0	33.3	77	70.1	2.6	27.3	2.9	10.5
WKST-4	99	63.6	28.3	8.1	99	48.5	28.3	23.2	23	65.2	0	34.8	76	63.2	3.9	32.9	2.3	8.3
WKST-5	98	59.2	26.5	14.3	98	46.9	26.5	26.5	26	46.2	0	53.8	72	63.9	1.4	34.7	2.2	25.0
WKST-6	95	55.8	32.6	11.6	95	43.2	32.6	24.2	23	52.2	0	47.8	72	56.9	2.8	40.3	1.7	14.5
WKST-7	98	68.4	21.4	10.2	98	61.2	21.4	17.3	17	41.2	0	58.8	81	74.1	6.2	19.8	3.2	3.2
WKST-8	96	72.9	20.8	6.3	96	59.4	20.8	19.8	19	68.4	0	31.6	77	74.0	9.1	16.9	3.5	1.9

Table 1a

Sample No.	Total Points Counted for Roundness	Angular %	Sub-angular %	Sub-rounded %	Rounded %	Total Number for Undulatory extinction	Undulatory extinction % (Minerals with distortion)	Non-undulatory extinction % (Minerals without distortion)
WKST-1	101	70.3	15.8	9.9	4.0	97	4.1	95.9
WKST-2	99	67.7	16.2	10.1	6.1	92	26.1	73.9
WKST-3	95	81.1	11.6	7.4	7.4	89	68.5	31.5
WKST-4	99	72.7	11.1	13.1	3.0	91	25.3	74.7
WKST-5	98	75.5	10.2	10.2	4.1	84	26.2	73.8
WKST-6	95	72.6	14.7	3.2	9.5	84	27.4	72.6
WKST-7	98	79.6	6.1	11.2	3.1	88	42.0	58.0
WKST-8	96	75.0	13.5	7.3	4.2	90	38.9	61.1

Table 1b