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Studies on Sandstones in the Maizuru Zone, Southwest Japan I

Importance of some Relations between Mineral Composition and Grain Size

By

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Abstract

Sandstones of the Permian and Triassic Groups in the Maizuru Zone*, Southwest Japan, were studied. Especially, the relation between mineral compositions and grain sizes was examined from the view point of "maturity". As a result, the importance of selective transportation of various kinds of components has been pointed out and emphasized in this paper.

Introduction

What caused the difference of mineral composition of sandstones, is a repeatedly discussed problem in respect to the subject of sandstone classification.

Two factors are usually treated in the discussions: one is the property of source rocks, and the other the maturity of the sandstone. The broad concept of "maturity" was introduced by PETTIJOHN (1949) and PLUMLEY (1948) to describe the approach of a sediment to the most inert end state possible, through the opperation of both physical processes and chemical processes. FOLK (1951) studied the textural side of maturity in detail, and he (1954) stressed the need of distinction between grain size and mineral composition in sedimentary rock nomenclature. As for the relation between them, however, there are still some problems left to be investigated.

The writer has studied the Permian and Triassic Sandstones in the Maizuru Zone, Southwest Japan. In this paper, he wishes to examine the relation between mineral composition and grain size of these sandstones, from the viewpoint of sandstone maturity.

The number of pages being limited, the mineral compositions of each sandstone

* For the stratigraphical studies on the Zone, the reader is referred to NAKAZAWA's paper (1957).

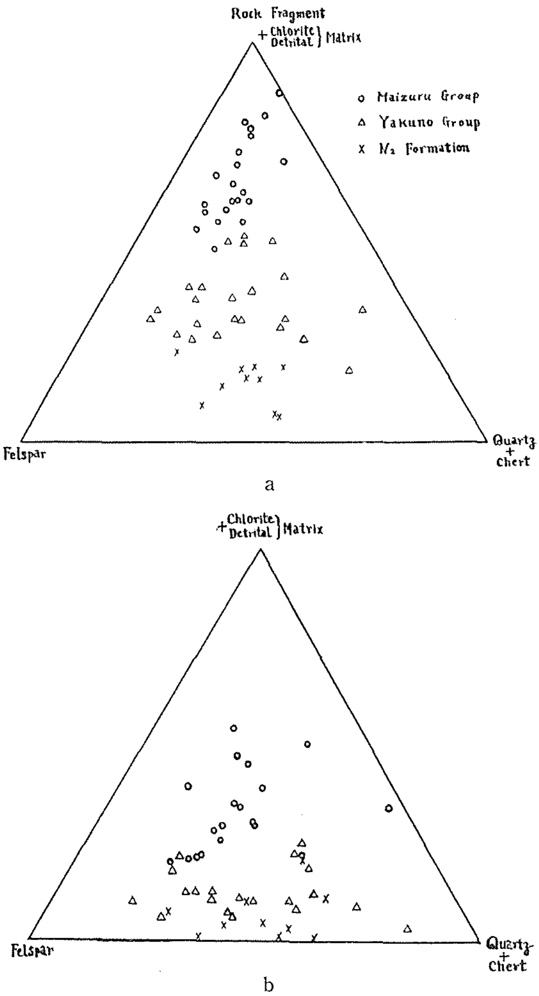

Fig. 1 a, b. Diagram showing mineral composition of sandstone.

are shown in diagrams (Fig. 1 a, b). More detailed descriptions of each component, and the data of field observations will be reported in an other paper.

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Quartz index, felspar content, and maturity

As illustrated in Fig. 2, in the case of sandstones of the Yakuno Group (Lower to Middle Triassic), the approximate tendency shows that the amount of felspar decreases with the increase of quartz (including chert) content.

It is generally recognized that the amount of quartz indicates the mineralogical maturity of sandstones. And Plumley (1948) regards the decrease of felspar as the expression of the mineralogical maturity. These ideas are based on the fact that quartz is the most durable essential mineral in sandstone and that felspar has a much larger tendency to break up during the course of weathering and transportation. Judging from these considerations, the quartz-poor (felspar-rich) sandstone of the Yakuno Group may be taken to be an immature sandstone, and the quartz-rich (felspar-poor) sandstone of the Group may be regarded as a mature one.

By the way, as shown in Fig. 3 a & b, the amount of quartz or felspar of the sandstones of the Yakuno Group varies according to the mean size of sand grains, i.e., the larger the mean size of the grains, the larger amount of quartz and the smaller amount of felspar are contained. If the matter shown in the figure is considered jointly with the judgment about the mineralogical maturity of the sandstones, the following conclusion may be introduced. In the case of the sandstones of the Group, the coarser grained

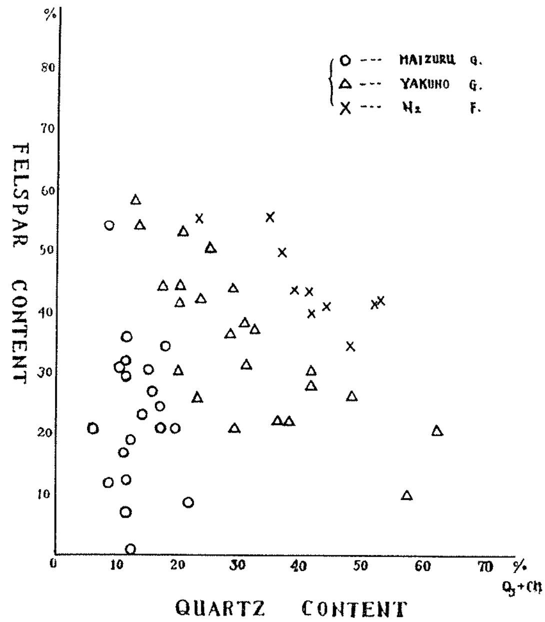

Fig. 2. Relation between amounts of quartz (including chert) and felspar.

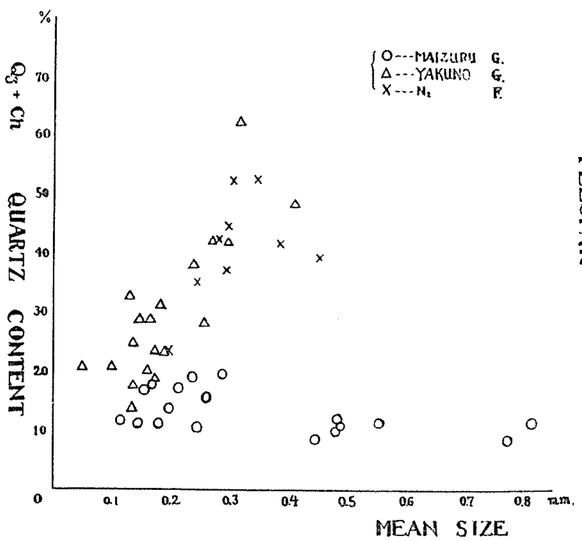

Fig. 3 a. Relation between quartz content (including chert) and mean size of sand grains.

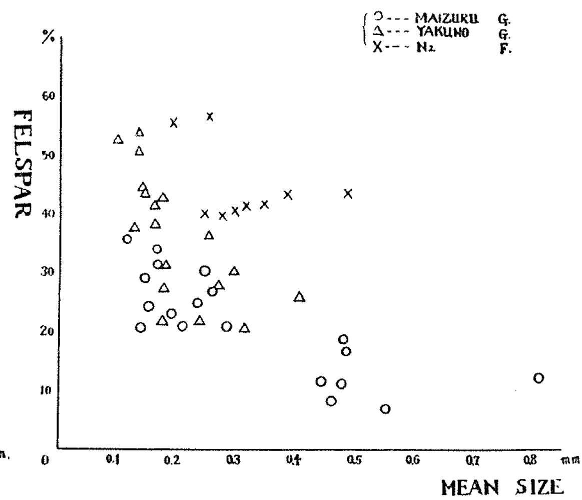

Fig. 3 b. Relation between amounts of felspar and mean size of sand grains.

sandstones contain the larger amount of felspar, and so they should be redarded as the more mature sandstones; on the contrary, the sandstones of the finer mean size have the smaller amount of quartz and the larger amount of felspar, so that they must be an immature sandstone.

In general, a sand grain must be abraded and broken up, during the course of transportation, and become smaller and smaller. According to KRUMBEIN and SLOSS (1953), the data of the beach sand of Half Moon Bay, California, show a systematic decrease in average grain size, and an improvement in sorting, in the direction of movement. Similar relation between grain size and distance of transportation, has often been studied. It is true that, such decrease of grain size of sediments owes almost entirely to sorting rather than abrasion or breaking. But it is not reasonable to consider that the longer the sand grains are transported, and the higher the maturity they reach, the larger the grains become. Consequently, the former conclusion concerning the maturity, must be criticized as a thought involving some mistake.

This question may be solved by examining the place, to which the broken-up felspars are transported.

As PLUMLEY (1948) stressed, the felspar grains have a tendency to break up mainly due to its particular properties of cleavage. These grains which have become smaller, must make motions different from those of larger grains under the velocity of stream. As mentioned before, the main cause which arranges the grain sizes of sediments is sorting rather than abrasion. This was experimentally studied in detail and was emphasized by KIMURA (1953–1956). According to him, in the first stage of the sorting, sediment grains are sorted by the difference of the critical current velocity required for their movements. In the second stage, the moving grains are sorted by difference of the manners of their movements (for instance, carried in suspension and traction). In the third stage, the grains carried in suspension and traction are sorted respectively by the difference of their settling velocity and that of their traction velocity.

By this mechanism, felspar grains, which have been broken and made smaller, move more rapidly than quartz grains. Accordingly, felspar may be separated gradually from quartz and concentrated in the other places where current velocity decreases enough to let the finer grains settle. The fact that, when the mean sizes of sand grains come below 0.25 mm or so, felspar increases notably in quantity, seems to ascertain the above consideration.

In short, the water current breaks up felspar selectively from detritus mixed of quartz and felspar. And then, felspar is separated selectively from quartz. This is, however, not due to mineralogical character of felspar but to its fineness. Thus, in one place, quartz-rich coarser grained sands are accumulated, and in another place, felspar-rich finer grained sands are deposited.

The amount of quartz may represent maturity, when examined in some unit of study. And the decrease of felspar may express maturity as Plumley says. But, it cannot be said that felspar-rich sandstone are immature than quartz-rich ones.

Similar considerations as those stated above in the case of the Yakuno Group, may also be possible in the case of the sandstones of the Maizuru Group (Upper Permian). In this case, the amount of quartz of the sandstones is extraordinarily small, so that the distinct relation between the quartz amount and mean size of the sand grains cannot be known. But, between the felspar amount and mean size, a similar inclination can be recognized, that is, when the mean size decreases the amount of felspar increases. This inclination may be explained also, as in the case of the Yakuno Group, by the selective breaking and selective transportation for felspar grains.

The sandstones of the N_2 formation of the Nabae group (Upper Triassic), are characterized by the abundance of both quartz and felspar. But the materials are too small in number to find the relation between the mean size and amount of quartz or felspar.

Breaking of rock fragments and maturity

Similar problem as stated with felspar also arises with rock frangments. For instance, the sandstones of the Maizuru Group contain a large amount of fragments of andesite, shale, etc., that can be regarded very indurable against weathering or breaking. These rock fragments decrease in accordance with the decreasing of mean size of sand grains, and especially fall off when the mean size becomes smaller than 0.2–0.25 mm (Fig. 4). However, rock fragments are unlike felspar in the manner of breaking. They do not seem to have the tendency to attain the size of 0.25–0.1 mm. But decompose directly to finer muddy or clayey matters. The fact that, when mean size becomes smaller than 0.25 mm the sandstone contains much clayey detrital matrix (Fig. 5), seems to confirm the above consideration.

Generally speaking, clayey matters made by decomposition of rock fragments during transportation, may join with other clayey materials which have been

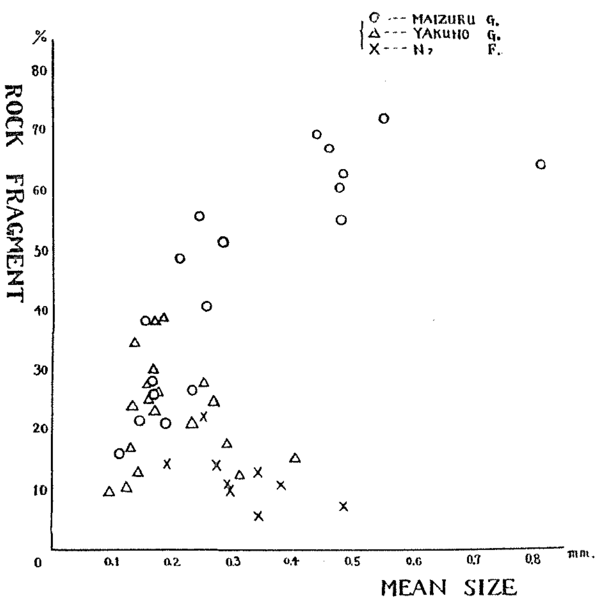

Fig. 4. Relation between amounts of rock fragments and mean size of sand grains.

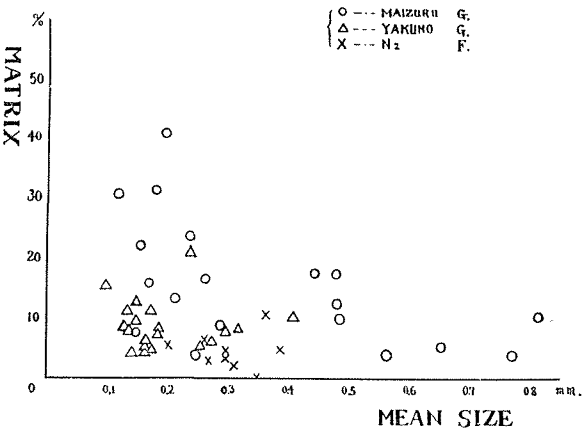

Fig. 5. Relation between amount of detrital matrix and mean size of sand grains.

produced by weathering at their provenance. These clayey matters may selectively be separated by sorting action from sand grains, and may compose clayey sediments at some other places apart from the place where sand is deposited. But in the case of the Maizuru Group, owing to its peculiar mechanism of transportation and sedimentation, the separation of clay was poorly done, and much of the clayey detrital matters formed the matrix of the sandstones of the Group.

As for the sandstone of the Yakuno Group, such a distinct relation between the amount of rock fragments and mean size, cannot be found. Of course, also in the case of the Group, the sediments coarser than granule size have a lot of rock fragments (which also include volcanic rocks, shale, etc.), and they contain little amount of clay matrix. So, the fact itself that, sand size sediments do not contain many rock fragments, seems to reflect the selective breaking and immediate decomposition of rock fragments without passing the particles of sand or silt size. The fact shows, accordingly, that the removal of the clay is also due to the different modes of motion of sediment grains of various sizes.

In reality, the abundance of rock fragments in sandstones of the Maizuru Group, must itself be an expression of the peculiarity of the depositional mechanism of the Group, and shows that the sandstones of the Group are more immature than those of the Yakuno Group.

To sum up, it may be said that, between the amount of rock fragments and other components, are found the same problems as found between felspar and other components, though the manner of the expression of the problem varies according to the Groups to which the sandstone belongs.

Relation between the mineral compositions and the grain sizes

Generalizing what the writer has examined in the above chapters, he ventures to state as follows.

In short, the mineral compositions of sandstones are closely related with the sizes of the grains. In the case of immature sandstone, the relation is not distinct.

The higher the maturity of sandy sediments becomes, the clearer the relation can be recognized. Felspar is concentrated in the part of sizes below 0.25 mm and perhaps above 0.1 mm. Quartz gathers in the part above 0.25 mm. Rock fragments, especially basic to intermediate volcanics and shale fragments, are not contained in large amounts in general sandstones. But in peculiarily immature sandstones (for example, in the sandstones of the Maizuru Group), especially in those coarser than 0.25 mm in size, a large amount of rock fragments are contained. In general, clayey matters may selectively be separated from sand grains. In some case, however, (for instance, in the case of the Maizuru Group) these clayey detrial matters were deposited together with sands, especially with those finer than 0.25 mm in size, and composed the detrital matrix of the sandstones.

This relation is connected at first with the properties of each kind of components, namely, whether it tends to be broken up and to decompose or not, during the course of weathering, transportation and deposition, and the sizes the broken pieces tend to take. After these components attain their respective grain sizes corresponding to their mineralogical properties, the water current sorts out the grains according to their sizes. Thus, from an immature sandy deposit of some mineralogical composition, more mature deposits rich in specular components are made. For example, the decrease of felspar followed by the increase of quartz in some places, and the accumulation of felspar separated from quartz in other places are the two aspects of a result of a series of process. Hence, if the term "muturity" is to be used, the felspar-rich finer sandstone and the quartz-rich coarser sandstone should be considered to be in the same stage of maturity.

From the above-stated studies it follows that, for the examination of the maturity of sandstones, we should consider both the compositional properties and the textural properties, and especially their mutual relation. The maturity of sandstone should never be commented on, from only the amount of quartz, felspar, or clayey matrix directly and mechanically.

Besides the problems stated above, it should be considered that, the kind of source-rocks is also a very important factor to be examined in the study of properties of sandstones. For instance, the compositional properties of the sandstones of the N_2 formation, rich in both quartz and felspar, may be due not only to their maturity, but also to the nature of their provenance. Studies of sandstones like these, should be further carried out in relation to sedimentary environments and tectonic movements. On these subjects, investigations will be reported on other occasions.

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