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四川乐山大佛砂岩的成因

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提要 四川乐山地区上白垩统夹关组红色砂岩到底是水成的还是风成的已经争论了很久。许多人根据它宏观的沉积构造特征认为是风成砂岩，但并未提出令人信服的证据。为了解决这一问题，本文作者从沉积构造、垂向序列、粒度分布特征，石英砂表面特征等四个方面详细论证了这套砂岩的确形成于干旱的沙漠环境，但不时受到间歇性河流的影响。

该区典型的垂向序列由粒度明显不同的两套岩石组成。中到下部为细到中粒长石石英砂岩具巨型斜层理，属内陆砂丘成因。上部粉砂岩具沙纹层理，含钙质结核和泥质纹层，属间歇性片流沉积。粒度分析和石英砂扫描电镜分析有力地支持了这一结论。

综合分析区域地层学和岩相古地理资料可知，晚白垩世时乐山地区处于干旱气候下距西部山前冲积扇不远的沙漠环境。

主题词 干旱气候 沙漠环境 白垩系 砂岩乐山

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THE ORIGIN OF LESHAN GREAT BUDDHA SANDSTONE IN SICHUAN PROVINCE

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Preface

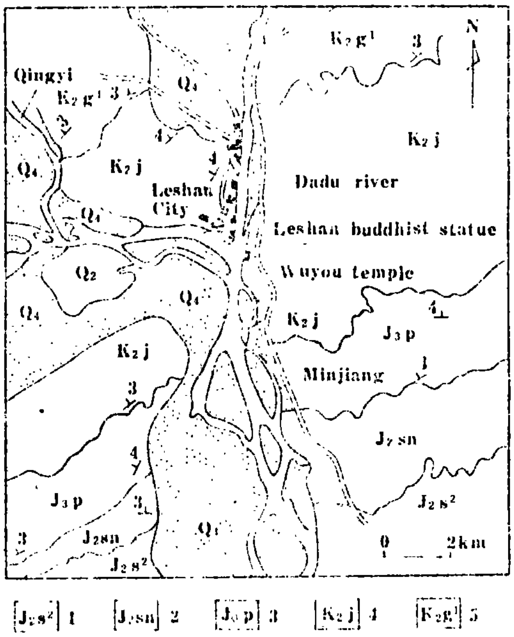
The historic famous city-- Leshan is located in the southwestern part of Sichuan basin. Three rivers-- Mingjiang, Daduhe and Qingyijiang converge here, and the worldfamous Leshan great buddha with a thickness of 70m is serenelly siting on the cliff by the Mingjiang river, facing the distant city.

The red sandstone from which the statue was carved is very attractive and interesting to geologists for its large-scale cross-beddings and unique sequences. In this paper, the origin of the red sandstone will be discussed in detail.

Gelolgical Background

Leshan city is located in the southwestern margin of Sichuan basin where the Upper Shaximiao For. and Suining For. of Middle Jurassic, the Penglaizheng For. of Upper

Jurassic, the Jiaguan For. and Guanlou For. of Upper Cretaceous are exposed extensively, but the Tianmanshan For. of Lower Cretaceors is absent. The attitude of stratum is gentle and smooth. The buddhist statue was just carved in the red sandstone of Lower Jiaguan For. (Fig.1)



1.Upper Shaximiao For.; 2.Suining For.; 3.Pengleizheng For.; 4.Jiaguan For.; 5.Guankou For.

Fig.1 Geological map of Leshan area

The Jiaguan For. is 424 meters thick, and mainly consists of thickmassive fine–grained feldspar–quartzose sandstone, but has siltstone and shale interlayers in the middle part.

The isochronous sediment of Jiaguan age becomes coarser northwestward, and in Guansian— Baosing area it is dominated by conglomerate. Southeast– ward it becomes thick– bedded inequigranular argillic feldspar– quartzose sandstone with mudstone interlayers.

The Guankou For. is a salty succession, mainly purple siltstone and mudstone with gypsum and salt.

The evidences of eolian sandstone

It has been argued for a rather long time whether the formation of the red sandstone is of aquatic or eolian origin. But what acturlly happend? most geologists think of it as an eolian sandstone because of its large–scale cross–beddings. Now we have initially confirmed the idea through recent research works. The evidences are as follows:

1. Sedimentary structures The large-scale cross-beddings are widespread (photo5, 6) . The set-thickness ranges from one meter to eight meters, mostly are 2—5m. The lamina-thickness ranges from three meters to sis meters. The dip-angle of foreset generally ranges from 21° to 29°, the maximun is up to 40°. The large-scale cross-bedding can be divided into three sub-types: The first type is huge-scale tabular cross-bedding which is frequently found in the fine-medium grained sandstone of the middle-lower part of a sequence, and the dip-angle of foreset is 27°-30°. The second type is huge-scale trough cross-bedding, its set-thickness is up to five meters. The dip-angle of foreset in the upper part is 26°-28°, but downward it becomes nearly tangential to the set-interface. The third type is gently declined or parallel bedding, and generally appears in the lower part of some sequences.

2. Petrological characters Feldspar-quartzose sandstone is the major rock-type. The total content of feldspar and lithoclast is about 30%, it indicates that the component maturity is very low. The grains are well rounded, the sorting is comparatively good in the same grain-size group of some samples with bimodal grain-size distribution (photo2). The packing density is high, and there is no clay matrix, mica content is less than 1% of the rock. This indicates that the texture maturity of the rock is very high. All the grains are coated by red hematite films (photo 1), indicating a hot and arid environment.

In some sequences, the upper section is dominated by siltstone with calcareous concretions and clay straps. Its texture and component maturity are both very low, and it seems not to be a eolian sandstone.

Studing the surface characters of quartz grains with SEM, it is found that all the angles of the grain were rounded (photo 3). The grain surface were frosted, on which various collision traces can be observed. Most collision traces are V-shaped percussion pits. The grain surfaces, including some pits are mostly covered by SiO_2 upturned plets, and even a film was formed. The later collisions had made the film broken and upturned, so the surface looks very disorderly (photo 4). The formation of these SiO_2 plets resulted from the process: that is, the quartz minidetritus produced by the percussion between grains in the daytime were resolved by dew in the night, then some noncrystalline SiO_2 precipitated from the solution the next day.

3. grain-size characters The sorting of the fine-grained sandstone with tabular and trough cross-bedding is generelly good (SD = 0.54—0.75). The grain-size distribution is much concentrated (K = 4.9—5.1). The cumulative frequency curve of grain-size shows a single saltation population which may be on association of two or more subpopulations. The obliquity is very steep (Fig.2, A-1, B-1), and there is no suspension population. In the lower part of The sequence, the grain-size distribution of fine-medium grained sandstone with tabular or parallel beddings is partially biomodal (Fig.3, A-1), and the difference between two modals is 1.4Φ.

The veidences mentioned above indicate that most rocks of the sequence were formed by dunes. But in its upper part, the cumulative frequency curve of the grain-size distribution of siltstone with ripple cross-bedding is composed of a saltation population and a suspension population. The later is about 10% (Fig. 2, C-3), and consists of little clay matrix. The siltstone has a medium souting (SD = 0.89), and a relatively concentrated grain-size distribution (K = 4.7). The grain roundness is lower than that of the lower sequence, generally subangular. These features indicate that the siltstone is not and dolian rock, but a kind of Sediment formed by ephemeral flood stream.

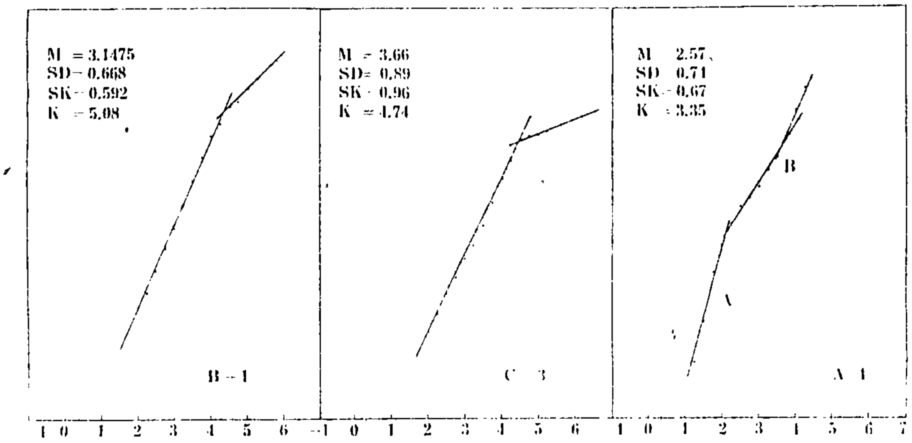
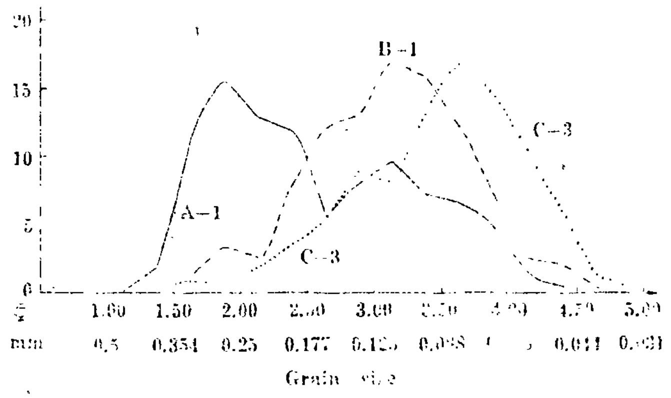


Fig.2 The cumulative frequency curves of Grain-size of the sandstone



A-1: medium grained fedspar-quartzose sandstone

B-1: fine grained feldspar-quartzose sandstone C-3: siltstone

Fig.3 Grain-size distribution curves of sandstone

4. The vertical sequence The typical vertical sequence in Leshan area is shown as Fig.4 and photo 6. The sequence is generally composed of two groups of rock types with different grain–size.The large–scale cross–bedding section (B.C) and the parallel–bedding section (A) represent the sandstone formed by inland dunes.Its component maturity is Low, but its texture maturity is very high.This indicates the eolian sandstone was formed through reworking the previous fluvial sediment.The dip of foreset in sandstone varies rapidly, but only two groups of dips dominate the others.One group is about NE 55°—65°, the other is about SE 114°—140°, the first group is more common.This indicates that the predominant wind direction is SW–NE.In addition, the variation of the stratifications may have reflected the difference of the dune–shape.for example, the parallel bedding may be more related with barchan of transverse dune (Glennie, 1972).

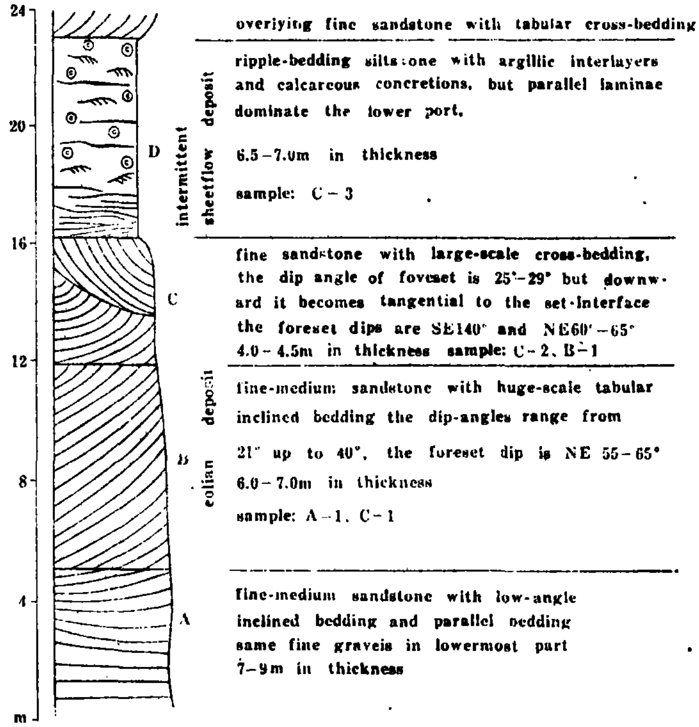


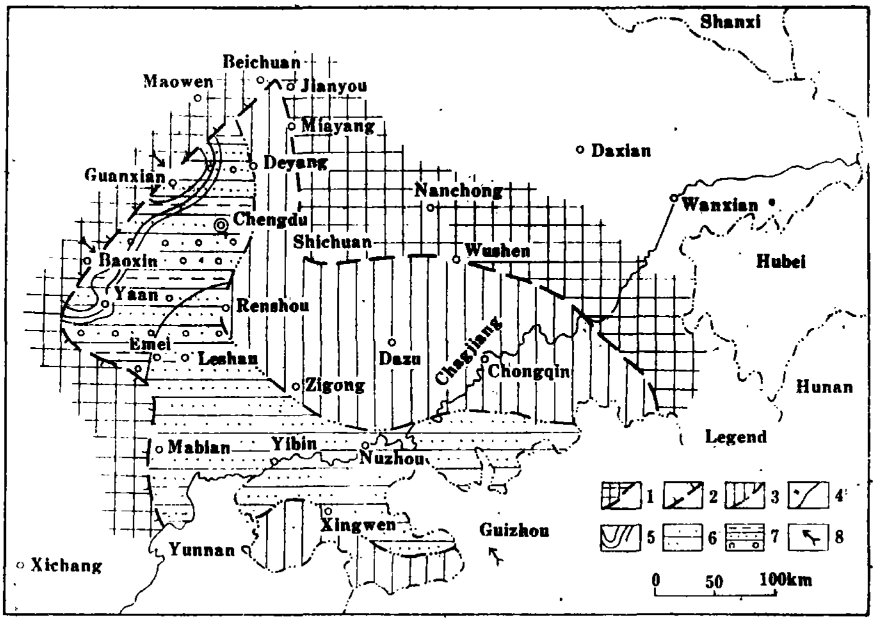
Fig.4 The typical vertical sequence of sandstone in Leshan area.

The ripple–lamine section (D) in the upper sequence is dominated by siltstone in which a great many calcareous concretions and clay straps can be seen.It imples a kind of intermittent sheetflow depsit near the distal fan in dry and arid weather conditions.

These vertical sequences (generally 10–30m thick) occur repeatedly in this area.In some places, the lower parallel–bedding section (A) is absent.In other places the thickness of section D is more than ten meters.This indicates that the dune shape, dune scale and the deposition of the intermittent streame were different in different places.But the vertical sequences are always composed of the inland dune facies in the lower part and the ephemeral flood stream facies in the uppermost part.

Reconstruction of the paleoenvironment

In the end of Jurassic period, the southern, central and eastern parts of Sichuan basin began to rise rapidly, and then became high land. So the basin shrank to a cresent lake northwestward. After the deposition of Chengqian Group (conglomerate) in the Early Cretaceous period, the northern part of the basin rose continuously, and the sedimentary basin shrank further to a narrow belt of Chengdu–Leshan–Yibin. At that time, the alluvial sieve conglomerate was deposited in front of Mt. Longmen, i. e. Baoxin– Guanxian area. Southeastward to Leshan–yibin area, it became very thick bedded red sandstone. Further southeastward to the northern Guizhou province, it changed into a fluvial sandstone with mudstone interlayers.



1. the margin of sedimentary basin and hilly area; 2, the fault boundary of basin; 3, eroded area and its boundary. 4, the boundary of facies regions; 5, alluvial fan; 6–7, desert environment; 6, eolian sandstone with interlayers of siltstone and mudstone formed by sheetflow; 7, sandstone and conglomerate of fluvial and alluvial fan facies; 8, the supply direction.

Fig.5 Lithological and paleogeographical map of Sichuan Basin at Jiaguan age of Later Cretaceous period.

According to the study above, it is clear that the red sandstones were mostly formed by inland dunes: The presence of ferric films and calcareous concretions indicates the weather of the Later Cretaceous period was arid. Through the synthetical analysis of regional data, it is clearly shown that the whole Sichuan basin (much small than before) was a dry and hot desert except for the sorthern basin margin and Mt.Longmenshan front of the western basin margin, where fluvial deposits and alluvial fans had developed (Fig.5). Because Leshan area was compararively near the western alluvial fans, and was frequently influnced by the distal sheet flow (or ephemeral braided stream so-called) from the fans at flood period, an upper sequence of the flood stream was formed in this way.

In the end of Cretaceous period (Guankou age) the weather was continuously arid. A deposit of saline lake facies was precipitated in Leshan area.

References

1. Liu Baojun, Zeng Yunfu, 1985, The basic Knowledges and Methods of Lithofacies and Paleogeography, Geological Publishing House.

2. Long Xueming, 1987, Geological Field Trips Guidebook in Sichuan, China, Chengdu College of Geology.

3. Richard A. Davis, Jr., 1983, Depositional Systems, pp.169–200, Prentice-hall, INC., Englewood Cliffs, New Jersey 07632.

4. Xia Zonshi, Wang Mengyun, 1984, The Stratigraphy and Paleontology of The Terrestrial Strata of Sichuan Basin, pp.209–235, The people's Publishing House of Sichuan.

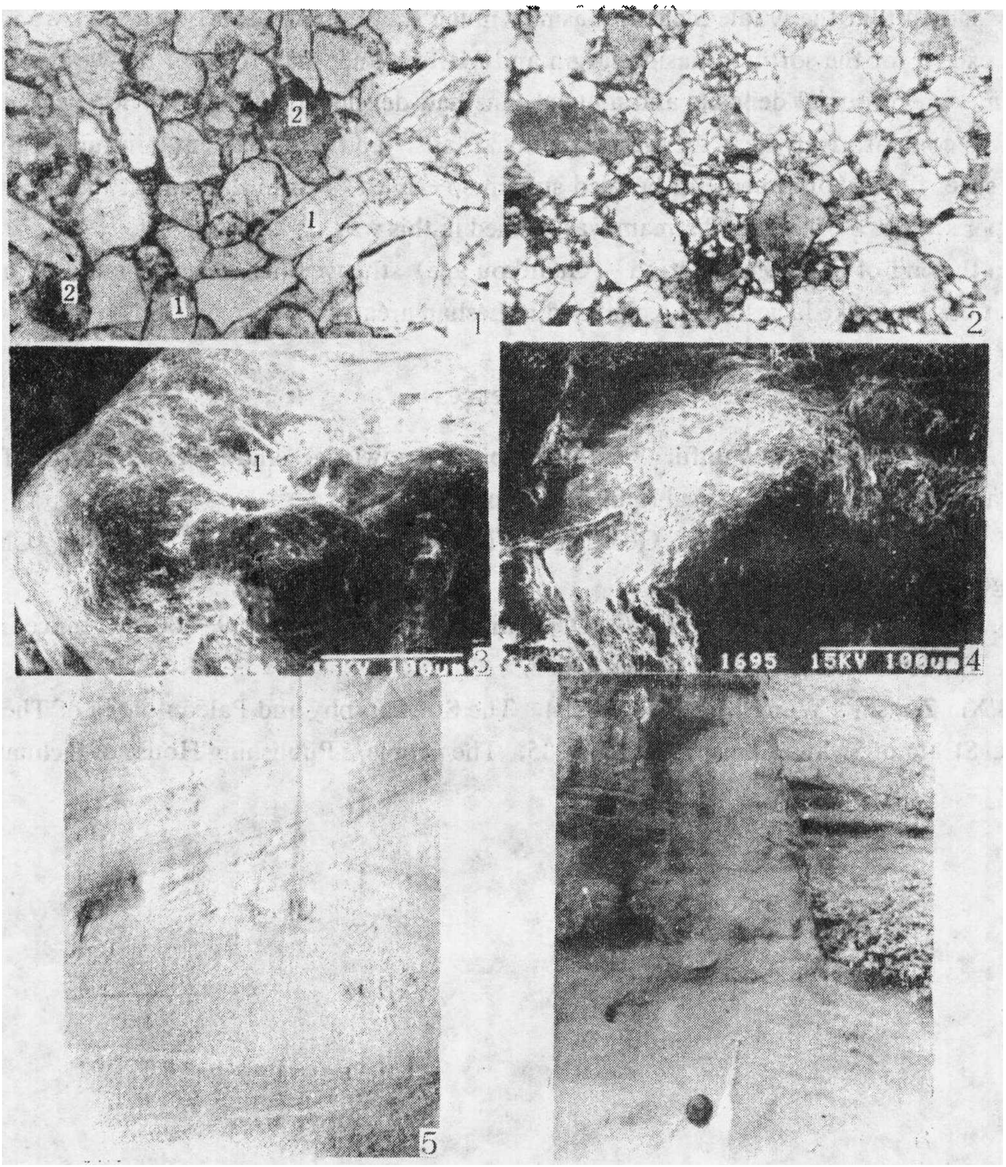


Photo 1, All the sand grains were well rounded and coated by hamitite films, no clay matrix. Many feldspars (1) and lithoclasts (2) can be seen in the photo. Thin secxtion c—4, ×40 Photo 2, The sorting is compara—tively good in the same grain—si—ze grorp of some sandstone with bimodal grain—size distribution. Thin section c— 1, ×40 Photo 3, A well rounded puartz grain. Some Sio2pletes deposited in the pits (1) of the grain sur—face. SEM photo, A—1 Photo 4, The frosting surface of a puartz grain which was well rounded. SEM photo by Zhang Changjun. Photo 5, The large— scale cross——bedding in sandstone. The actual height represented by the photo is more th an 5 m. Photo 6, The Vertical Sepuence of Sandstone consisted of three parts: the lower part with large—scale tabular bedding, the middle part with parallel bedding and the upper part with ripple bedding.