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PRELIMINARY DISCUSSION ON THE ORIGIN OF LEI-GONG-MO (TEKTITES)

Yuan Baolin

Translation of "Hainan dao leigongmo (boliyuanshi) qi yuan wenti de chubu tantao", Scientia Geologica Sinicc, No. 4, October 1981, pp. 329 - 336.

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16. Abstract The specimens of Lei-gong-mo (tektites) which form the object of the present study were collected from Hainan Island and Leizhow Peninsula during the period from 1963 to 1975. The distribution, forms, sculpture, abration surface (bald spot), internal structure and chemical composition of Lei-gong-mo are discussed and the studies of these materials lead to the following conclusions:

1. The specimens of Lei-gong-mo so far known can be morphologically divided into eight types.
2. The sculptures on the surface of Lei-gong-mo are formed probably due to the corrosion effect of volcanic gas on it, and the abration surface due to the aerodynamic corrosion.
3. The folded structures in the layered Lei-gong-mo (Muong Nong-type tektite) seem hardly to be formed by an impact of meteorites, but they might be produced in the flow process of magma when the Lei-gong-mo was melting within the crater vent.
4. The comparison of its chemical composition with that of basalt from Hainan Island does not show that Lei-gong-mo came from the local volcano.

Based on the studies mentioned above, the author is inclined to agree with the hypothesis of the lunar volcanic origin of tektites.

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PRELIMINARY DISCUSSION ON THE ORIGIN OF LEI-GONG-MO (TEKTITES)

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Tektite is a type of natural glass. It's origin is a contro- /329*
versial problem in modern astrolithological research. Lei-gong-mo is a type of tektite discovered on Hainan Island and Leizhou Peninsula.

In 1844, the English biologist Darwin, who was the first to discuss the 'Theory of the Evolution of Man, reported on an Australite in a scientific article. His opinion was that it was a type of obsidian from a volcanic eruption.[1] This was later called "Darwin Glass". Although there was continuous progress in tektite research after this, a solution to the origin of tektite has yet to be found.

Lei-gong-mo was first given a vivid description by Liu Xun in the middle of the 10th century.[2] This is the earliest mention of lei-gong-mo. However, there is a lack of research on lei-gong-mo by modern scholars. It has only been mentioned in a few articles by Lacroix (3, 4, 5) in the thirties. In 1962 a specialized survey was carried out by Chinese scientist Li Daming on Hainan Island and Leizhou Peninsula. The results of this research were subsequently reported.[6]

In 1974, during the Hainan Island Quaternary Period Geological Survey, we discovered some lei-gong-mo in the Beihai Formation strata and published the results of research on the importance of

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* Numbers in the margin indication pagination in the foreign text.

lei-gong-mo to the study of the Quaternary Period stata and on the measurement of the age of lei-gong-mo by fission track. Few Chinese have dealt with the problem of the origin of lei-gong-mo. This paper will therefore carry out a preliminary investigation of this problem in order to stimulate input from other interested scholars.

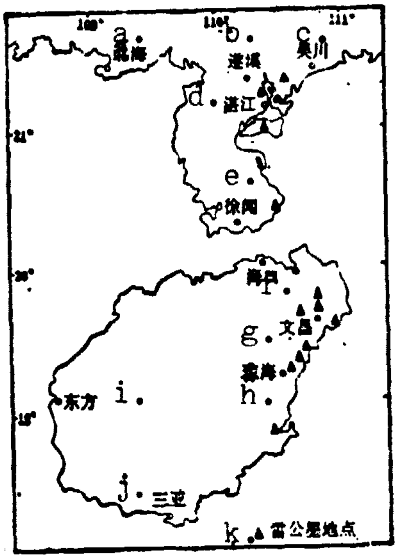


Fig. 1: Map showing distribution of lei-gong-mo. (L. Daming)

a. Beihai	b. Suixi	c. Wuchuan
d. Ganjiang	e. Xuwen	f. Haikou
g. Wenchang	h. Jinghai	i. Dongfang
j. Sanya	k. Lei-gong-mo locations	

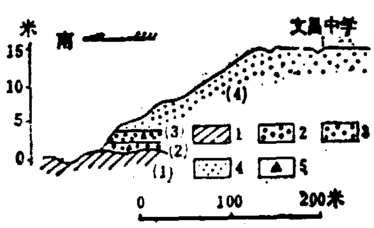
The author would like to express his gratitude to the following: Sun Shu, for providing several valuable specimens; Ye Lianfang and Wang Songshan, for measuring the absolute age of the samples and Li Dechun and Wang Degong for providing data on chemical analysis.

I - LEI-GONG-MO DISTRIBUTION AND ENVIRONMENT

Tektites are mainly distributed throughout four strewn fields in the world. These are; the Australasian, the Ivory Coast, the Moldavian and the North American strewn fields. Tektites from different areas all bear regional names, such as, australite, philippinite and libyan desert glass. The tektite from Hainan Island and Leizhou Peninsula is known as lei-gong-mo and belongs to the Australasian strewn field.

Hainan Island and Leizhou Peninsula lei-gong-mo is mainly distributed throughout Shenjiang, Chuwen, Wenzhang and Jinghai counties, of which Wenzhang and Jinghai have the richest deposits.

Figure 1 shows the distribution of lei-gong-mo in Jinglei, based on findings since 1962. Most of the lei-gong-mo samples were col- /330 lected from the earth's surface. In Wenchang and Wanning counties, however, they were collected from the Beihai Formation strata. Using the profile of Chengche, East Wenchang Middle School, Wenchang County as an example (Fig. 2), the beds (2) - (4) were continuous deposits of a bed of reddish brown fine sand and a bed of gravel. These beds are extensively distributed along the coast of Hainan Island and Leizhou Peninsula and can be compared with the Beihai Formation. The top surface is composed of a 30 m tertiary marine origin platform. The gravel and coarse sand beds contain lei-gong-mo which has not undergone abrasion. Other locations in the Beihai Formation strata where lei-gong-mo was discovered are; Luazai, Longlou, Tanniu, Taishan village, all in Wenchang County and Kan Tianchang in Wanning Country. A large quantity of lei-gong-mo was buried in well-graded fine sand beds.



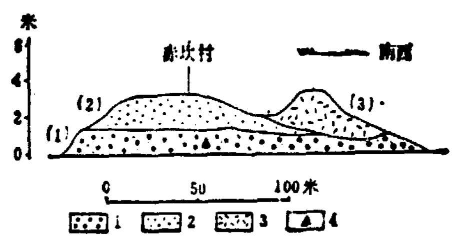


Fig. 2: Profile of Wenchang Middle School, Wenchang County

1. bedrock 2. gravel bed
3. coarse sand bed
4. fine sand bed
5. lei-gong-mo

3. Profile of Yintun Yikan Village, Wenchang County

1. gravel bed
2. fine sand bed
3. artificial accumulation
4. lei-gong-mo

Lei-gong-mo has been discovered on a 15 m secondary marine origin platform profile in Yintunyikan village in Wenchang (Fig. 3). The geomorphological position of the Yintun section of the Beihai Formation strata is low, and the extent of weathering is small. This means it must be of a later period than the Beihai Formation strata. The fact that the lei-gong-mo is rounded in some places shows that it originated from a disintegrated Beihai Formation stratum.

On the basis of these facts, there is reason to believe that the events which led to the geological formation of lei-gong-mo must have happened during the period of deposition of the Beihai Formation stratum. Non-abraded lei-gong-mo with a diameter of 3-5 cm appears in the well-graded fine sand stratum. This is clearly not from material usually transported by landflow or sea water. A more logical explanation is that this is from material that has fallen from outer space.

II - THE SHAPE, SURFACE STRUCTURE AND INTERNAL STRUCTURE OF LEI-GONG-MO

1. Shape

Lei-gong-mo varies in shape. There are roughly eight types of lei-gong-mo which have presented their specific forms intact (plates 1-9):

(1) Layered: Irregular shape, has a distinct thin layered structure, generally in strata from 0.5 - 3 mm thick.

(2) Elliptical: Long sphere-shaped, one pole small, one pole large. The long axis is twice the length of the short axis. The long vertical axis is circular in cross section.

(3) Teardrop: Resembles an elongated teardrop, the long axis is more than three times as large as the short axis. The long vertical axis is circular in cross section.

(4) Dumbbell: The two poles are slightly rod-shaped.

(5) Rod: Generally 3-5 cm in length, circular in cross section. Cross section diameter is generally less than 1 cm.

(6) Lenticular: Only one piece of lenticular lei-gong-mo was collected. It was 5 cm in diameter, 3 cm thick in the centre and thinner towards the edges.

(7) Broken walnut shell: Curved slice with thickness of 3-5 mm.

The negative camber has flow streaks, whereas the positive camber has irregular pits and grooves.
(8) Flaky: 3-5 cm thick. Often has clear flow streaks.

Apart from the specific forms of lei-gong-mo described /331 above, there are also irregular gragments. It is either difficult to deduce their original form or these irregular fragments are their original forms.

Other tektite areas have shapes different than those described above. There are also button shaped, dug-out canoe-shaped and fruit-store shaped tektites.

The Australian button shaped tektite is the only one which has been thoroughly studied from the point of view of the formation of these shapes. Baker thinks that it was originally spherical and that while falling through the atmosphere at high speeds, the front dashed against air particles, was melted through friction and rapidly evaporated. A part of the molten liquid flowed to the back, accumulated and formed a ringed flange. This finally became a button shaped (10). This inference has been verified in laboratory experiments.

2. Surface Structure

The surface structure of lei-gong-mo is unusually complex. It can be divided into two classes; sculptured and abraded (plates 10-15).
(1) Sculptured: Refers to surface pits, grooves, air holes, furrows and flow streaks. Sculptured types are related to the shape of lei-gong-mo. Bedded lei-gong-mo has rather deep sculptured grooves extending along the bed and may reach a depth of 2-3 cm. The grooves are irregular in cross section. The surface of the lei-gong-mo with other shapes is mostly full of round pits and grooves. The grooves are U shaped in cross section and the direction is disorganized. Air holes are rarely seen on lei-gong-mo. On one specimen ellip-

soidal airholes, 11 mm in length were seen and a part of the joined outer shell (plate 15) was retained on the upper section.

Flow steaks can be seen on all shapes of lei-gong-mo. These flow streaks usually appear as slightly projecting lines with a diameter of between 0.03 - 0.15 mm. The length is usually the same as the lei-gong-mo.

A freshly cut section of lei-gong-mo is a conchoidal fracture and is abnormally glossy. However, on a cracked surface produced after falling to earth a fine curved furrow can be seen of about 0.1 mm in width and depth.

With respect to the origin of sculptured types there are three main view points: aeodynamic sculpuring, geochemical corrosion and corrosion caused by red hot gases at the time of volcanic eruption.

The anterior of the button shaped tektite (and the surface rubbed by air) is very shiny and there is no corrosion. Its posterior that is, its original spherical surface, has retained different types of sculpturing. This shows that they were present before the tektite entered the atmosphere and not the result of aerodynamic sculpturing. Nininger and Huss (11) studied two teardrop tektites. They had traces of a half split and the fracture had the form and structure of a plastic substance when opened. However, the top had no sculpturing. There were various sculpturing phenomena on the other parts. This shows that the surface sculpturing was already present when the tektite was first formed and still in a plastic state.

Is surface sculpturing the result of geochemical corresion? The answer is negative because button shaped tektites have not undergone corrosion ever a long geological period. Apart from this, the depth of sculpturing reached a depth of 2-3 cm in some specimens. If chemical corrosion had been carried out at such a speed that the diameter of the microtektite was less than 1 cm, it would have disappeared long ago. Furthermore, we saw curved minute patterns and pits on the breakage surfaces of some lei-gong-mc and the depth of sculpturing was very shallow. These could have been the result of geochemical corrosion.

Laying aside the first two possibilities, we are naturally made to consider the third possibility - that of volcanic gas corrosion. The red hot gases from volcanic erruption possess strong corrosive properties. It is entirely possible that this is how these sculpturings were produced.

(2) Abraded: This is the opposite of sculptured. It does not make the shape of the lei-gong-mo uneven but the sculpturing is ground even and the lei-gong-mo becomes shiny and smooth. Both sculpturings and abrasions are usually found on the same specimen. However, the abrasions only occupy part of the surface. There are often quite deep uneven sculptured furrows on the abraded surface, which shows that abrasion was later than sculpturing. On some samples, a slighty projecting crestline had formed at the intersection of the two abraded surfaces of the different parts mentioned above. Sometimes the abrasions resembled knife marks.

The process of abrasion in the button shaped tektite is already clear. Its abrasion is a shiny hemispherical surface. Almost all the abraded lei-gong-mo specimens have a curved smooth surface. /332
This cannot be the result of wind erosion. We think that these abrasions were produced by aerodynamic abrasion. When lei-gong-mo was falling through space it is possible that gravity and air resistance were not rectilinear on account of its irregular shape. This caused rotation and two or more directions were abraded. These shapes of lei-gong-mo were disadvantageous to the accumulation of molten material, so that only one type of polished shape was formed. O'Keefe after studying some abraded specimens, also thought that this was due to aerodynamic abrasion (9).

3. Internal Structure

The internal structure of lei-gong-mo is homogeneously vitreous.

No crystals could be found under a polarizing microscope. X ray diffraction also showed its structure to be vitreous. Internal flow streaking could be observed under a microscope. After lei-gong-mo had been polished and etched in 40% hydrofluoric acid for 30 seconds, the whole field of vision appeared pitted under a microscope.

The most important characteristic of the internal structure of tektites is that they are homogeneously vitreous. This distinguishes them from impact glass formed by impact modification. The outline of mineral crystals in the original rock can be observed in the latter under a microscope as well as the remaining unformed vitreous crystals (9). It can therefore be said that impact glass is a kind of inhomogeneous glass.

Several bedded lei-gong-mo have been discovered in Rendun, Jinghai County, Hainan Island. Those with flow streaks can also be observed. The direction of flow is parallel to the stratification. On some specimens a curved or a coiled thin layer was observed wedged between two parallel thin layers (plates 11, 14). A piece of lei-gong-mo 23 cm long, 12 cm wide, and 6 cm thick was also collected (plate 10). It weighed 1895 g. Its shape resembled a volcanic bomb. There was a very deep sculptured groove along the stratification. Flow streaking was extremely distinct. One pole of the specimen had what resembled abraded knife marks. The bedded structure must have been under melt flow for a long time before it could have formed. If the impact modification period had beed short, the molten matter could not have flowed sufficiently. At the same time, the pressure of impact could not have formed the curved and coiled structures described above either. Therefore there is reason to infer that bedded lei-gong-mo is a type of eruptive. Bedded structures were formed by flowing in the molten state a long time before eruption.

III - THE CHEMICAL COMPOSITION OF LEI-GONG-MO

Constant element and trace element analysis was carried out on six specimens of lei-gong-mo (Table 1). The results show that the range of change in different samples is very narrow. The change in content of SiO_2 was between 72.85% and 75.25%. For Al_2O_3 it was 11.52%-12.26%. The average iron content was 6.19%-7.5%. Furthermore Na_2O K_2O. This was the same for the lei-gong-mo from different locations, thus showing that they were the product of the same geologic /333
event.

The chemical composition of the tektite from the Australasian strewn field was basically the same. However, there were some set differences present in the chemical composition of the specimens from different locations. These may be divided into 11 different types (9). The lei-gong-mo from Jinglei and the standard Indo-Chinite were the same in chemical composition. O'Keefe used a triangular graphic method to distinguish the characteristics of tektites with respect to their chemical composition. His method consisted of taking the percentage of MgO and CaO and adding 0.05 of the percentage of S_1O_2. The average is shown by S. The difference between the three apices of the triangle show the percentage values of MgO/S, CaO/s and S_1O_s X 0.05/S. Thus the position of each type of tektite may be marked with a dot on the triangle after the above values have been calculated (Fig. 4).

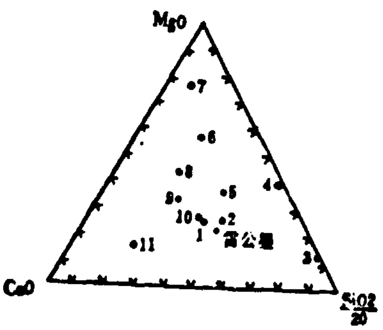


Fig. 4: The chemical composition of tektites (O'Keefe, 1976)

1. Normal australite
2. Normal indochinite
3. Darwin-Macedon glass
4. Darwin-Macedon glass
5. Low-calcium, high-aluminum tektite
6. High-magnesium tektite
7. Bottle-green Australasian microtektite
8. Normal Australasian microtektite
9. High Na/K
10. Normal philippinite
11. High-calcium philippinite

Standard australite is basically located in the centre of the triangle and standard indo-chinite is located near it. The location of lei-gong-mo and standard indo-chinite is extremely close, which proves that they belong to the same type. We used a fission track method and a potassium argon method to measure the absolute chronology of lei-gong-mo. It was approximately 700,000 years (Table 2). This was consistent with the values for the absolute chronology of tektites from other regions within the Australasian strewn field. This shows that they are the product of the same geological event.

There are several quadernary volcanoes distributed throughout northern Hainan Island and Leizhou Peninsula. There were many eruptions during the quadernary period. In order to compare the relationship between lei-gong-mo and volcanic activity in that region and basalt, we took two basalt specimens and carried out constant and trace element analysis. The results are given in Table 1.

The difference between the chemical composition of lei-gong-mo and basalt is extremely great. The SiO_2 content in basalt is a lot lower than in lei-gong-mo. There was only 48-54% in basalt. In basalt the Fe_2O_3 content was 10 times greater than that of lei-gong-mo, CaO was 4 times, MgO was 3-5 times, TiO_2 was 2-3 times and Na_2O was over twice as great. In terms of trace elements, the Ca content was clearly higher than lei-gong-mo. The La content could not be measured in basalt and it was less than 0.01 in lei-gong-mo. The Co content was less than 0.003 in basalt, whereas there was /334
a trace in lei-gong-mo.

A comparison of the chemical composition of lei-gong-mo and basalt shows enormous differences between the two. There is no certain relationship between them, which eliminates the possibility that lei-gong-mo is the product of volcanic eruption.

IV - THE ORIGIN OF LEI-GONG-MO

The origin of lei-gong-mo is the same as the origin of tektite. There have already been several hypotheses of tektite origin which

Basalt sample

Components	Longlouxi	Wenchangzhangxue	Tannui	Diluzai	Jinghai	Jingai 2	Average	Penglai	Jinnuiling
[illegible]	[illegible]	[illegible]	[illegible]	73.80	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Al_2O_3	11.52	11.97	11.79	12.26	11.32	11.33	11.69	13.37	15.78
Fe_2O_3	0.50	0.40	0.49	0.59	0.89	[illegible]	0.63	5.25	5.40
FeO	5.43	6.46	5.38	5.04	4.76	[illegible]	5.40	7.23	5.29
C[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.85
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9.75	[illegible]
[illegible]	[illegible]	0.11	0.11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.14
TiO_2	0.73	0.74	0.78	0.78	0.80	0.88	0.78	2.30	1.91
P_2O_5	0.11	0.12	0.08	0.12	0.34	0.28	0.18	0.64	0.29
K_2O	2.20	2.40	2.40	2.40	3.30	[illegible]	2.60	1.70	0.60
Na_2O	1.30	1.50	1.50	1.50	1.20	1.36	1.39	3.40	3.30
Total iron	6.53	7.57	6.46	6.18	6.19	6.79	6.60	13.28	11.07
Total amount	100.59	100.66	100.65	100.25	99.90	[illegible]		100.59	100.61
MgO/CaO	0.72	0.97	0.78	[illegible]	0.79	[illegible]	0.80	1.16	0.58
N_2O/K_2O	0.59	0.63	0.63	0.63	0.39	0.47	0.56	2	5.5

TABLE 1: CONSTANT AND TRACE ELEMENTS IN LEI-GONG-MO AND BASALT IN JINGHAI REGION

	Sample	K-Ar. ($X10^6$yr)	Authority	Fissiontrack ($X10^6$years)	Authority
Australasian strewn field lava	Australite	0.72±0.0[illegible]	Zähringer	0.7±0.[illegible]	Gentner et al
	Indo-Chinite	0.7[illegible]±0.06	Zähringer		
	Philippinte	[illegible]±0.07	Zähringer		
	Laosite				
	Darwin Glass			[illegible]	Gentner et al
	Manglongite			0.7±[illegible]	Gentner et al
	Microlava			0.71±0.1	Gentner et al
Lei-gong-mo	Diluzai			0.697	Ye Liangang et al.
	Longlouxi			0.728	Ye Lianfang et al.
	Wenchangzhongxue			0.703	Ye Lianfang et al.
	Tanniu	0.6[illegible]±0.037	Wang Songshan et al.	0.733	Ye Lianfang et al.
	Lingshui County			0.640±0.0[illegible]	Geochemical Institute
	Jinghai County			0.755±0.0[illegible]	Geochemical Institute

TABLE 2: ABSOLUTE CHRONOLOGY OF LAVA FROM AUSTRALASIAN STREWN FIELD AND LEI-GONG-MO

have been refuted. Currently under debate are those hypotheses mainly centred on terrestrial and lunar origins.

The terrestrial origin hypothesis includes the volcanic eruption and impact transformation hypotheses. Our research on lei-gong-mo indicate there are several facts which contradict the terrestrial origin hypothesis. For example; chemical analysis shows that lei-gong-mo is not the product of a local volcanic eruption. No clear connection has been found between tektites and volcanoes or lava in the four strewn fields currently in existence. Furthermore, bedded lei-gong-mo can only be formed after sufficient flowage under a molten state. Impact transformation cannot supply enough flowage time. The curved intercalation in bedded lei-gong-mo must have been formed by force applied parallel to the stratum face. There is no way that this type of force could originate from impact transformation.

Theoretically speaking, the hypothesis of a lunar origin is possible. The impact of aerolites from the moon's surface is extremely widespread. Recent research of some scholars shows that there could have been volcanic activity from the Cenozoic Period right up until the present (12). It is possible that matter from meteor impact and Volcanic eruption could have broken away from the moon's gravitation and fallen to the earth. Chapman (13) calculated the trajectory for lunar matter splashing down to the earth and several kinds of models for a landing orbit. Similar relationships may be found between the above and the distribution of several types of tektite in the Australasian strewn field. It can be seen that the hypothesis of a lunar origin can provide a more suitable explanation to tektite distribution. Some of the properties of lunar rock and lunar soil have several points in common with tektites. For example, both tektites and lunar rock have a low water content. Lunar soil samples contain several glass particles. Their shape, contain several glass particles. Their shape, surface structure and colour are very similar to terrestrial microtektites (12, /335
14, 15). It is possible they have a common origin.

Some of the properties of lei-gong-mo are more reasonably explained by the lunar origin hypothesis. For example the shape of lei-gong-mo is extremely similar to that of volcanic bullets and volcanic beans. It is possible that curved intercalations as well as flow streaked tektites were formed when lava flowed inside lunar volcanoes. Furthermore, sculptured lei-gong-mo may have been formed by the chemical corrosion of red hot corrosive gases on volcanic projections when there was volcanic emanation on the moon. After they entered the earth's atmosphere, they were formed into abraded shapes by aerodynamic abrasion.

In summary, the difficulties are fewer when the lunar hypothesis is used to explain the origin of tektites. Furthermore, proof has already been found that there is a connection between tektites and lunar substances. Therefore, the author supports the hypothesis of a lunar origin for tektites (lei-gong-mo). At the same time, he thinks it is possible that there is a relationship betwen lunar impact transformation and volcanic eruption and the origin of tektites. This is a path worth following in the study of the origin of tektites and lei-gong-mo.

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PLATE I

1. Layered lei-gong-mo; 2. Flaky lei-gong-mo; 3. Elliptical lei-gong-mo; 4. Elliptical lei-gong-mo 5. Teardrop lei-gong-mo; 6. Dumbbell lei-gong-mo; 7. Lenticular lei-gong-mo; 8. Broken walnut shell lei-gong-mo; 9. Irregular lei-gong-mo; 10. Giant layered lei-gong-mo. a. Side, b. Top. 11. Elliptical, curved layered lei-gong-mo; 12. Elliptical lei-gong-mo, a. Sculptured surface, b. abraded surface; 13. Teardrop lei-gong-mo, a. Sculptured surface, b. abraded surface; 14. Curved, layered lei-gong-mo; 15. Lei-gong-mo with airholes.