

OPTICAL LENSES.

BY

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I. BURNING-LENSES IN CHINA AND INDIA.

FIRE-PRODUCTION BY MEANS OF OPTICAL LENSES AMONG THE ANCIENTS. — Crystal lenses, wherever employed in ancient times, served for one main purpose exclusively, — the optical method of fire-making. This method is not found among any primitive tribes of the world, but it is restricted to the highly advanced nations settled around the Mediterranean and to the peoples of India and China. W. HOUGH, in his interesting study *The Method of Fire-Making*,¹ has justly observed, “Among the several ways of producing ‘pure’ fire the mirror and lens presented a worthy method to those ancient cultured nations possessing instruments for focussing light. It can scarcely be said that this was a wide-spread and popular plan for producing fire, but probably was a thing known to priests and scientific men of the day, and viewed as a mystery or curiosity.”

The centre of gravity of the following inquiry lies in a new research of this interesting subject, as far as China and India are concerned.² China and India, however, were not isolated in the age

¹ *Report of National Museum*, Washington, 1890, p. 408.

² This study owes its origin to a suggestion received from Dr. Frank Brawley and Dr. Emory Hill, two prominent oculists of Chicago, who are about to issue a comprehensive cyclopædia of ophthalmology, and desire to obtain reliable information on the history of optical lenses in Asia. The second part of this essay will deal with the history of spectacles.

when the utilization of lenses loomed up on their horizons, but partook of the blessings of that great world civilization inspired and diffused by Hellenism. This subject therefore, like all other culture-historical problems, must be visualized within the frame of universal history; and it will hence not be amiss first to pass in review what we know of burning-lenses among the ancients in the western part of the world.

The peoples of classical antiquity were acquainted with two optical instruments for the production of fire, — concave burning-mirrors and convex burning-lenses focussing the sunlight. The question as to whether these are to be attributed to the inventive genius of the Greeks, or were modelled by them on the basis of previous achievements of Mesopotamian civilization, cannot be decided in our present state of knowledge. H. LAYARD¹ (1845) discovered in the palace of the Assyrian King Ashur-našir-pal (885—860 B.C.) at Nineveh a rock-crystal lens of plano-convexity, $1\frac{1}{2}$ inches in diameter, with a focus of $4\frac{1}{2}$ inches, cut much like our own burning-glasses, though somewhat crude in its workmanship. It may well have performed the function of a burning-lens, as admitted by modern technologists;² but we should await more evidence before crediting the first invention of burning-lenses to the nations of the Euphrates Valley.

The earliest well-authenticated literary testimony for the use of burning-lenses remains the famous scene in Aristophanes' (c. 450—c. 385 B.C.) comedy *The Clouds* (Νεφέλαι), written in 423 B.C., where the following dialogue ensues between Strepsiades and Socrates (I quote from T. Mitchell's rendering).³

¹ *Discoveries among the Ruins of Nineveh and Babylon*, p. 197.

² NIEMANN and DU BOIS (in KRÄMER, *Der Mensch und die Erde*, Vol. VII, p. 162); and FELDHAUS, *Technik der Vorzeit*, col. 667.

³ The situation is this: Strepsiades, who has run up a debt of five talents, wants to dodge his obligation by destroying the bill of complaint recorded in wax by operating on it a burning-lens.

- STREPSIADES. I've hit the nail
That does the deed, and so you will confess.
- SOCRATES. Out with it!
- STREPSIADES. Good chance but you have noted
A pretty toy, a trinket in the shops,
Which being rightly held produceth fire
From things combustible —
- SOCRATES. A burning-glass,
Vulgarly call'd —
- STREPSIADES. You are right; 'tis so.
- SOCRATES. Proceed!
- STREPSIADES. Put the case now your bailiff comes,
Shows me his writ — I, standing thus, d'ye mark me,
In the sun's stream, measuring my distance, guide
My focus to a point upon his writ,
And off it goes in fumo!
- SOCRATES. By the Graces!
'Tis wittingly devis'd.

This translation is somewhat free, and does not bring out the technical points which are of importance for a consideration of the burning-lens. Strepsiadēs describes it as a beautiful and diaphanous stone (*λίθος διαφανής ἀφ' ἧς τὸ πῦρ ἀπτουσι*); and what Socrates in the above translation calls a burning-glass is in the Greek *hyalos* (*ὑαλός*). It is presumed that this word here appears for the first time in Greek literature in the sense of "glass,"¹ and accordingly that Aristophanes speaks of burning-lenses made from glass.² The reasons given in support of this opinion, however, are by no means convincing. The first Greek author with a distinct mention of glass is Herodotus (II, 69), who terms it "molten stone" (*λίθος χυτή*) with reference to the ear-rings placed by the Egyptians in the ears of their tame crocodiles. Herodotus (III, 24) likewise is the first to use the word *ὑαλός* in the description of the coffins of the Ethiopians, where it most evidently has the significance of "rock-crystal" or some other

¹ BLÜMNER, *Technologie*, Vol. IV, p. 384.

² M. H. MORGAN, *De ignis eliciendi modis apud antiquos* (*Harvard Studies in Classical Philology*, Vol. I, 1890, p. 46). This is the most complete study of Greek and Roman methods of fire-making, inclusive of burning-lenses and burning-mirrors.

transparent stone;¹ for “they put the prepared body in a crystal pillar hollowed out for this purpose, crystal being dug up in great abundance in their country.”² If ὕαλος has in Herodotus, as shown by the inward evidence of the passage, the meaning of “rock-crystal,” I see no reason why the same meaning should not be attributed to it in Aristophanes. Besides the passage cited, there is but one other in which the great writer of comedy makes use of the word: in *The Acharnians* the Greek ambassadors, returning from a mission to the King of Persia, report,

“At our reception we were forced to drink
Strong luscious wine in cups of gold and crystal,”³

as J. H. Frere translates with perfect correctness; where Blümner, Morgan, and others, however, see the first mention of glass vessels in Greek records.⁴ It seems to me more probable that gold and crystal vessels are here spoken of. In order to succeed in making the burning-lenses mentioned in *The Clouds* of glass, Morgan is obliged to have recourse to two theories which are unsupported by evidence. We see plainly from the words of Aristophanes, he observes, that glass was very rare in his time (while two pages ahead glass utensils were then at Athens), since he calls it a precious stone (*gemma*); and, as it is said that this stone is for sale in the shops of the pharmacists (*pharmacopola*), it is proved by this very fact that the matter was regarded as a miracle. This “miracle” will fade away, if we adopt the reasonable and natural interpretation of taking ὕαλος in this passage as “rock-crystal” with the specific sense of “burning-

¹ Some authors take it for Oriental alabaster or arragonite, which is transparent when cut thin.

² Thus also Achilles Tatius calls rock-crystal ὕαλος ὀρωρυγμένη.

³ Ἐξ ὑαλίων ἐκπαυμάτων.

⁴ MORGAN (*L. c.*, p. 44) says with regard to this passage that glass utensils were at Athens as early as in Aristophanes' times; the passage, in my opinion, would allow only of the inference that they were at the Court of Persia, and dimly known to Aristophanes.

lens of crystal;"¹ and we are thus released from the necessity of making Aristophanes speak of glass as a precious stone. Strepsiades' description fits "crystal" very well indeed. There are other, historical reasons which warrant the belief that the first burning-lenses were cut from crystal, not from glass, as will be shown by a study of this subject from Chinese and Sanskrit sources.

M. H. MORGAN,² it is true, makes the point that rock-crystal became known only at a late period in classical antiquity, shortly before Augustus; and he reveals the Roman poet Helvius Cinna, and Strabo, who mentions the occurrence of crystals in India, as the earliest authorities. This opinion, however, is not correct. Rock-crystal (ἡ κρύσταλλος) is distinctly alluded to by Theophrastus (372—287 B.C.)³ as a translucent stone together with anthrax, omphax, and amethyst, all of which can be turned into signet-rings.

More important than the material of which the burning-lenses of the Greeks were made is the question as to their purpose and mode of use. The scene in Aristophanes' comedy enlightens us in this respect on two points. The effect of a burning-lens was perfectly known. The legal document of which Strepsiades speaks was certainly draughted on a tablet of wax, and related to a debt which he contracted; he intends to foil his creditors by melting the wax by

¹ This interpretation is adopted by LIDDELL and SCOTT in their *Greek-English Lexicon*.

² *Harvard Studies in Classical Philology*, Vol. I, pp. 44, 48—49.

³ *De lapidibus*, V, 80 (opera ed. WIMMER, p. 345, Paris, 1866). This fact is indicated also by KRAUSE (*Pyrgoteles*, p. 16) and SCHRADER (*Reallexikon*, p. 152). Theophrastus is the first Greek author to speak of rock-crystal. As is well known, the word κρύσταλλος occurs in Homer, but has the significance "ice" (derived from κρύος, "chill, frost"); an analogous example is presented by Hebrew *gerah* meaning "ice" and "rock-crystal." The actual utilization of the mineral is certainly much older than the allusions to it in literature. It occurs among the material listed for cylinder-seals in Mesopotamia (HANDCOCK, *Mesopotamian Archaeology*, p. 287) and among the intaglios of the Minoan, Mycenaean, and archaic Greek periods (D. OSBORNE, *Engraved Gems*, pp. 25, 283). On rock-crystal among the ancients, in general compare L. DE LAUNAY, *Minéralogie des anciens*, Vol. I, pp. 22—28; and C. W. KING, *Antique Gems*, pp. 90—97.

means of a burning-lens, and thus to escape judicial proceedings. Such action was not the order of the day, but the specific witty thought sprung by Strepsiades, at which Socrates laughs. The destruction of writs, therefore, was not the real object of burning-lenses; what they really were intended for we may infer from the allusion that they were kept in the shops of the pharmacists. At this point Morgan went somewhat astray by neglecting the statement of Pliny, quoted below, who assures us that crystal lenses were employed in medical practice for cauterizing the skin; and if the Chinese adopted this very same process, the chances are that also the druggists of Athens in the fifth century B.C. kept burning-lenses in stock, not for any fanciful, miraculous purpose, but with a somewhat realistic end in view, — to sell them as instruments useful in certain surgical operations. Cauterization was practised to a large extent in ancient times; and many forms of the cautery were devised, numerous specimens of which have survived.¹

THEOPHRASTUS, in his treatise on fire, mentions crystal, bronze, and silver, when wrought in a certain manner, as means of igniting fire.²

PLINY (23--79), in his *Natural History*, makes two references to burning-lenses, both of crystal and glass. In his chapter on crystal he says, "I find it stated in medical authors that crystal balls placed opposite to solar rays are the most useful contrivance for cauterizing the human body."³ It will be noticed that the Chinese physicians

¹ J. S. MILNE, *Surgical Instruments in Greek and Roman Times*, pp. 116—120. Milne (p. 5) asserts, "The writings of Pliny contain little information of any kind and are absolutely of no use for our purpose;" but Pliny's references to burning-lenses, quoted above, would have found a suitable place in his chapter on cauteries, and assisted in enlightening the text of Hippocrates on p. 120.

² Ἐξάπτεται δὲ ἀπὸ τε τῆς ὕελου καὶ ἀπὸ τοῦ χαλκοῦ καὶ τοῦ ἀργύρου τρόπον τινα ἐργασθέντων (*De igne*, 73; opera ed. WIMMER, p. 363). Others cancel the words ἀπὸ τε τῆς ὕελου and interpret the instruments as concave mirrors (MORGAN, *l. c.*, p. 52).

³ Invenio apud medicos, quae sint urenda corporum, non aliter utilius uri putari quam crystallina pila adversis opposita solis radiis (SXXVII, 10, § 28).

made use of crystal lenses for exactly the same purpose. In the other passage it is remarked, "If glass balls filled with water are exposed to sunlight, they produce such a vigorous heat that they will ignite clothes." ¹

LACTANTIUS, the eminent Christian author of the third and fourth centuries, apparently under Pliny's influence, writes that when a glass globe full of water is held in the sun, fire will spring from the light reflected from the water, even in the severest cold. ²

ISIDORUS, the learned Bishop of Sevilla (570--636), observes that crystal opposed to solar rays attracts fire to such a degree that it ignites arid fungi or leaves. ³ His knowledge is evidently based on Pliny.

Besides the passages in Pliny we find a clear mention of crystal lenses in the *Orphica*, or *Λιθικά* of Orpheus, — a Greek poem wrongly associated with the name of Orpheus, and describing the magical properties believed to be inherent in stones, and revealed by the seer Theodamas to Orpheus. It is not, as formerly assumed, a work coming down from around 500 B.C., ⁴ but it manifestly bears the ear-marks of the late Alexandrian epoch, and is a production of post-Christian times. Crystal opens the series of stones dealt with in this work (Verses 170--184). The deity cannot resist the prayers of him who, bearing in his hand a refulgent and transparent crystal, betakes himself into a temple: his wish will surely be granted. When crystal

¹ Cum addita aqua vitreae pilae sole adverso in tantum candescant, ut vestes exurant (xxxvi, 67, § 199).

² Orbem vitreum plenum aquae si tenueris in sole, de lumine quod ab aqua refulget ignis accenditur etiam in durissimo frigore (*De ira Dei*, x).

³ Hic (crystallus) oppositus radiis solis adeo rapit flammam ut aridis fungis vel foliis ignem praebet (*Origines*, xvi, 13, 1). Fungi used in cauterization are mentioned by Hippocrates and Paul.

⁴ KRAUSE, *Pyrgoteles*, p. 6. The exact date of this work is not satisfactorily established (compare BERNHARD, *Grundriss d. griech. Lit.*, Vol. II, pt. 1, p. 359; and SUSEMILH, *Gesch. d. griech. Lit. in der Alexandrinerzeit*, Vol. 1, p. 866).

is placed on dry wood-shavings, while the sun-rays strike it, smoke will soon arise, then fire, and at last a bright flame, regarded as sacred fire. No sacrifice is more pleasing to the gods than when offered by means of such fire.

The ancients, accordingly, employed optical lenses in medicine for cauterizing the skin, and in the religious cult for securing sacred fire. The opinion has been expressed also that they served the purpose of magnifying objects, with reference to a passage in *SENECA*, that letters, however minute and indistinct, appear larger and clearer through a glass ball filled with water.¹ *LESSING*² has ingeniously and conclusively demonstrated that there is a wide step from a magnifying-sphere to a magnifying-lens, and that the causes of the enlargement were sought by the ancients, not in the spherical shape of the glass, but in the water with which it was filled. Moreover, the passage of *Seneca* proves nothing beyond a personal experience of that author; and there is, in fact, no ancient tradition regarding specular or magnifying lenses. In *Pompeii*, *Nola*, and *Mainz*, lenses have been excavated, of which *J. MARQUARDT*³ says that they could have been nothing but magnifying-lenses. I am unable to admit the force of this conclusion, and think that these lenses were simply burning-lenses.⁴

BURNING-LENSES IN THE MIDDLE AGES AND AMONG THE ARABS.—
The European middle ages are doubtless indebted to the ancients for whatever knowledge of this subject then existed. The mineralogical knowledge of this period is mainly based on the important work of

¹ *Litterae quamvis minutae et obscurae per vitream pilam aqua plenam maiores clarioresque cernuntur (Quaestiones naturales, i, 6, 5).*

² *Briefe, antiquarischen Inhalts, No. 45.*

³ *Privatleben der Römer, p. 752.*

⁴ *M. H. MORGAN (Harvard Studies in Classical Philology, Vol. I, 1890, p. 46)* sides with *Marquardt* and *Sacken* against *Lessing*, but on insufficient grounds, and evidently without taking serious notice of *Lessing's* forcible arguments.

the French Bishop of Rennes, MARBODUS (1035—1123), entitled *De lapidibus pretiosis*, and written in Latin hexameters. This poem, largely founded on Pliny, Solinus, and the Orphica, conveyed the classical traditions regarding stones to mediæval Europe, became the direct source of at least four French *Lapidaires*, and successfully maintained its place as the great pedagogical manual on precious stones and as the classical handbook of the schools of pharmacy down to the end of the sixteenth century.¹ In § 41 of his work, Marbodus makes the following observation on crystal lenses:

“But true it is that held against the rays
Of Phœbus it conceives the sudden blaze,
And kindles tinder, which, from fungus dry
Beneath its beam, your skilful hands apply.”²

As regards the further development of this matter, suffice it for our purpose to quote from KONRAD VON MEGENBERG'S (1309—78) *Book of Nature*, — “If the sun shines on a round crystal, it ignites tinder in like manner as the beryl does; if it is round like an apple, and if it is exposed to the sun while it is moist, it ignites extinguished coal,” — and to refer to the *Opus maius* of ROGER BACON (1240—92),³ who attempted to analyze the operation of a burning-lens. But Bacon's essay is dependent on that of the Arabic physicist Ibn al-Haiṭam (or Alhazen, 965—1039), who treated the problem much more profoundly and scientifically.⁴

¹ Compare the interesting discussion of L. PANNIER, *Lapidaires français du moyen âge*, pp. 15 et seq. (Paris, 1882).

² Translation of C. W. KING, *Antique Gems*, p. 411. In the earliest French translation (PANNIER, *l. c.*, p. 61) this passage runs thus: “Ceste conceit le fou vermaeil, | Ki la tient el raî del soleil, | E de cel fou li tondre esprent | S'il i tuchet alges sovent.”

³ *The “Opus maius” of Roger Bacon*, ed. by J. H. BRIDGES, Vol. I, p. 113 (Oxford, 1897).

⁴ Compare S. VOGL, *Physik Roger Bacos*, p. 80. — In regard to the more recent employment of burning-lenses, it is said that some Old-English tobacco-boxes have a lens in the lid for use on emergency; and naturalists still make occasional use of their pocket-lenses as a substitute for a match (*Horniman Museum and Library, Handbook on Domestic Arts*, I, p. 35).

Arabic knowledge of crystal lenses, again, is founded on that of classical authors, and mainly linked with the name of Dioscorides. In the Arabic version of the *Materia Medica* of this Greek author, compiled by Ibn al-Baiṭār (1197—1248), we find it stated that rock-crystal struck by hardened iron yields abundant sparks; ¹ that a piece of black linen subjected to the rays emitted by this stone, when it is exposed to solar light, will be ignited and consumed; and that it may be employed in this manner in order to obtain fire. ² The Arabic *lapidarium* of the ninth century, traditionally but wrongly ascribed to Aristotle, mentions the sparks of crystal in the same manner, but omits the reference to lenses, which, however, occurs in the Hebrew and Latin translations of the same work. ³ QAZWINI, the Arabic encyclopædist of the thirteenth century (1203—83), observes, "If rock-crystal is placed opposite the sun, and if a black rag or a flake of cotton is brought near it, the latter will catch fire, and objects may be lighted with such fire. There is still another kind of rock-crystal, less pure than the former, but harder; whoever beholds it, takes it for salt. If struck with hardened steel, however, sparks will easily spring from it; hence it serves as strike-a-light for the men of the kings." ⁴

¹ The ancient Laplanders made ample use of rock-crystal in the place of flint, and an eye-witness who tried the experiment assures us that rock-crystal struck by the steel yields more sparks than flint (J. SCHEFFER, *Lapland*, p. 416, Frankfurt, 1675). Also in the prehistoric ages of northern Europe, quartzites served for the production of fire (compare the interesting study of G. F.-L. SARAUX, *Le feu et son emploi dans le nord de l'Europe aux temps préhistoriques*, in *Annales du XXe Congrès archéol. et hist. de Belgique*, Vol. I, Gand, 1907, pp. 196—226, chiefly, pp. 213 *et seq.*).

² L. LECLERC, *Traité des simples*, Vol. III, p. 342.

³ RUSKA, *Steinbuch des Aristoteles*, pp. 170, 171. The Latin text runs thus: "Bonitas huius lapidis est quod quando exponitur soli rotundatus ut radii solares penetrent ipsum erit ignis ab eo" (*ibid.*, p. 207). The word *rotundatus* denotes a burning-lens.

⁴ RUSKA, *Steinbuch aus der Kosmographie des al-Qazwini*, p. 9. E. WIEDEMANN (*Sitzungsberichte der phys.-med. Soz. Erlangen*, Vol. 36, 1904, p. 332) remarks that the Arabic author omitted the word "globe" after "rock-crystal;" and he thinks it notable that Qazwini expressly speaks of rock-crystal.

Likewise in their knowledge of burning-mirrors, the Arabs depend upon the science of the Greeks, as shown in their discussions of this subject by references to Anthemius and Diocles.¹

REFUTATION OF THE THEORIES THAT THE ANCIENT CHINESE WERE ACQUAINTED WITH BURNING-LENSES. — In passing on to China, we face a bewildering jungle of speculations and opinions as to our subject; and only after clearing this jungle will it be possible to discuss the real facts in the case. If Dr. E. HILL² recently stated that "it is said that a Chinese emperor used lenses as early as 2283 B.C. to observe the stars," we here find expression of that popular opinion which credits the Chinese with lenses prior to the Greeks, — an invention which, as will be seen, was never made by the Chinese themselves. A lens could not have been manufactured at that time, as the materials required for it, glass or rock-crystal, were then unknown in China. Moreover, the Chinese in this case lay no claim whatever to a lens. The text from which this alleged lens (I do not know by whom) has been distilled is contained in the oldest historical record of the Chinese, the *Shu king* (II, 5), in which the astronomical activity of the Emperor Shun is spoken of: he is said to have availed himself of an instrument of jade, the description of which is not given in the text, but only by the late commentators.³ Whatever this instrument of hard, untransparent stone may have been, it surely has nothing in common with a lens.

Even professional sinologues, like SCHLEGEL,⁴ and quite recently FORKE,⁵ have asserted that burning-lenses were known to the Chinese

¹ WIEDFMANN, *Sitzungsberichte der phys.-med. Soz. Erlangen*, Vol. 37, 1905, p. 402.

² *Ophthalmic Record*, Vol. 23, 1914, p. 504.

³ See LEGGE, *Chinese Classics*, Vol. III, p. 33; COUVREUR, *Chou king*, p. 14; CHAVANNES, *Mémoires historiques de Se-ma Ts'ien*, Vol. I, pp. 58—59; and the writer's *Jade*, pp. 104 *et seq.*

⁴ The views of Schlegel are discussed farther on.

⁵ *Lun-hêng*, pt. 2, pp. 496—498.

in pre-Christian times long before they were known to the Greeks. Their conclusions, however, rest on a fallacy due to misunderstandings of the texts. We shall closely examine these, and see how those scholars were prompted to their opinions. It will be demonstrated at the same time that optical lenses of crystal or glass were absolutely unknown in China prior to our era.

Se-ma Chêng of the eighth century A.D. records, in his *Memoirs of the Three Early Sovereigns* (*San huang ki*), the following legend regarding the mythical being Nü-kua or Nü-wa, conceived as a serpent with a human head: ¹ "He fought with Chu-yung [the regent of fire] and failed in victory. Flying into a rage, he butted with his head against Mount Pu-chou and brought it down. The pillar of heaven was broken, and the corners of earth were bursting. Nü-kua then fused five-colored stones to repair the firmament, and cut off the feet of a marine tortoise to set up firmly the four extremities of earth. He gathered the ashes of burnt reeds to stop the inundation, and thus rescued the land of Ki. Thereupon the earth was calm, the sky made whole, and the old order of things remained unchanged." ² The same tradition is contained in the book going under the name of the alleged philosopher Lie-tse, ³ the present recension of which, in all probability, is not earlier than the Han period; likewise in the book of Huai-nan-tse of the second century B.C., ⁴ and in the *Lun-hêng* of Wang Ch'ung. ⁵ The latter philosopher points it out as a very ancient tradition believed by most people.

¹ Originally a male sovereign, but from the second century A. D. represented on the bas-reliefs of the Han period as a woman.

² Compare CHAVANNES, *Mémoires historiques de Se-ma Ts'ien*, Vol. 1, pp. 11, 12; H. J. ALLEN, *Ssüma Ch'ien's Historical Records* (*Journ. Roy. As. Soc.*, 1894, p. 274); MAYERS, *Chinese Reader's Manual*, p. 162; HIRTH, *Ancient History of China*, p. 11.

³ Ch. 5, *T'ang wên* (compare E. FABER, *Naturalismus bei den alten Chinesen*, p. 104; L. GILES, *Taoist Teachings from the Book of Lieh Tzû*, p. 85; L. WIEGER, *Les pères du système taoïete*, p. 131).

⁴ *P'ei wên yün fu*, Ch. 21, p. 217.

⁵ A. FORKE, *Lun-hêng*, pt. 1, p. 250; pt. 2, p. 347.

Every unbiased student will recognize in this legend concerning Nü-kua a genuine myth, in which a cosmological catastrophe is hinted at, the havoc wrought to heaven and earth being repaired with realistic expedients contrived by a primitive and naïve imagination. He whose trend of mind is bent on interpretation may fall back on the phenomenon of the rainbow, which may have impressed a primitive mind as consisting of stone-like patches for mending the sky after the destructive force of a rainstorm; and the brilliant colors of a quartz or agate may have intimated an association of ideas between the hues of a stone and those of the iris. The composite coloration of a stone may have suggested the effect of a smelting-process; at all events, the molten stones of a legend cannot be taken literally; the casting of metal is naïvely transferred to stones. Be this as it may, or whatever our interpretation of the myth may drive at, it is obvious to every sober mind that the elements of a fantastic myth, which is not reducible to an analysis of actual reality, cannot be utilized as the foundation of far-reaching conclusions as to industrial achievements of the Chinese. Some of our sinologues, however, were of a different opinion. The melting of the five-colored stones ascribed to that fabulous being was a rather tempting occasion for the exercise of ingenious speculations. MAYERS¹ championed the idea that the stone of five colors is coal, the useful properties of which Nü-kua was the first to discover; and T. DE LACOUPERIE,² in a very interesting article, took great pains to demonstrate that the legend has nothing to do with the introduction of glass and the discovery of mineral coal, though by no means himself arriving at any positive result.

Wang Ch'ung,³ in connection with a fire-making apparatus for

¹ *Notes and Queries on China and Japan*, Vol. II, p. 99.

² *T'oung Pao*, Vol. II, 1891, pp. 234-243.

³ *Lun hêng*, Ch. 16, p. 2 (ed. of *Han Wei ts'ung shu*). FORKE, *Lun-hêng*, pt. 2, p. 351.

drawing fire from the sky, mentions the practice, that "on the day *ping-wu* of the fifth month, at noon, they melt five stones to be cast into an instrument that is capable of obtaining fire." According to FORKE,¹ Wang Ch'ung speaks of burning-glasses as, "The material must have been a sort of glass, for otherwise it could not possess the qualities of a burning-glass."² Flint glass, of which optical instruments are now made, consists of five stony and earthy substances, — silica, lead oxide, potash, lime, and clay. The Taoists, in their alchemical researches, may have discovered such a mixture." By interpreting the terms *yang sui* 陽燧 or *fu sui* 夫遂 as "burning-glass," Forke reads of burning-glasses even in the *Chou li*, and is finally carried to this conclusion: "Burning-reflectors were known to the Greeks. Euclid, about 300 B.C., mentions them in his works; and Archimedes is believed to have burned the Roman fleet at Syracuse in 214 B.C. with these reflectors, — probably a myth. Plutarch, in his life of Numa, relates that the Vestals used to light the sacred fire with a burning-speculum. As the *Chou li* dates from

¹ *Ibid.*, p. 496.

² It will be seen below that this conclusion is a fallacy, and is in fact inadmissible; but, granting for a moment its *raison d'être*, the technical point is not so easily settled, as represented by Forke. Wang Ch'ung does not speak of five different stones, but, as demonstrated farther on, indeed speaks of five-colored stones with a distinct allusion to the Nü-kua legend; his term *wu shi* 五石 in this passage being merely a loose expression or abbreviation for *wu se shi* 五色石. If, then, a multi-colored stone is here in question, and if this stone could be identified with a kind of quartz, Forke's opinion, from a technical point of view, would not be utterly wrong; for it is technically possible to make glass from quartz. This experiment was successfully carried on about a decade ago by C. Heraeus in Hanau: the quartz utilized was melted in vessels of pure iridium, which melts at 20000, while the melting-point of quartz is at 17000. After exceeding its melting-temperature, the quartz becomes glassy. The process itself is difficult and complex, and it would be unreasonable to suppose that a technical manipulation which has succeeded only in our own time should have been familiar to the ancient Chinese, who derived from the West whatever knowledge of glass they possessed. If, however, the "five-colored stone," as shown below, was a variety of agate or soapstone (and this opinion is highly probable), nothing remains of Forke's theory.

the eleventh century B.C. (?), it is not unlikely that the Chinese invented the burning-reflector independently, and knew it long before the Greeks."

TH. W. KINGSMILL once remarked,¹ "Myths have been not inaptly described by Max Müller as a disease of language; and to this category we may perhaps relegate the group of modern myths which have grown up in and around our descriptions of China and its arts." I apprehend that the assigning to the ancient Chinese of burning-lenses belongs to this category of modern myths based on mis-interpretation of terms. BIOT,² SCHLEGEL,³ HIRTH,⁴ and CHAVANNES⁵ have clearly shown that the fire-apparatus spoken of in the *Chou li* was a metal mirror, and the Chinese commentators claim no more for it; even Forke cites their opinion, yet mechanically clings to his idea of burning-glasses. Unfortunately, he omits to tell us how the Chinese of the Chou period — when even a word for "glass," and certainly the matter itself, were unknown to them — should have obtained glass. And if the molten stones of Wang Ch'ung, in Forke's opinion, are glass, the molten colored stones of Nü-kua would be entitled to the same consideration; and thus the baffling result would be attained that not only burning-glasses, but also glass in general, are truly Chinese inventions, the latter going back to the dim past of prehistoric ages.

An intimation that the five-colored or variegated stone is a reality, is first given by Li Tao-yüan 麗道元, who died in A.D. 527, in his commentary on the *Shui king* 水經注, a book on the rivers of China:⁶ "On the northern side of the Hen Mountains, along the

¹ *Chinese Recorder*, Vol. VII, 1876, p. 43.

² *Le Tcheou-li*, Vol. II, p. 381.

³ *Uranographie chinoise*, p. 612.

⁴ *Boas Anniversary Volume*, pp. 226—227.

⁵ *Le T'ai Chan*, pp. 188—189.

⁶ Compare CHAVANNES, *T'oung Pao*, 1905, p. 563.

Ki River, the rocky hills border the river so closely that there is no space for flat beaches; in places where the water is shallow there is plenty of five-colored stones."¹ In another passage he refers to carvings from the stone of the same name, which served for the decoration of a palace of the Emperor Wên of the Wei dynasty in A.D. 220.

The *Yün lin shi p'u* 雲林石譜 by Tu Wan 杜綰 of 1133² likewise makes mention of five-colored stones 五色石 in the Ki River 溪水 near Sung-tse 松滋, in the prefecture of King-nan 荆南府 (now King-chou), in the province of Hu-pei. Among these are some almost transparent, intersected by numerous lines that are straight like the fibres of a brush, and not different from the agate of Chên-chou 眞州.³

Another tradition crops out in the Gazetteer of Lai-chou 萊州志,⁴ according to which the district of Ye 掖縣, forming the prefectural city of Lai-chou on the northern coast of Shan-tung, would produce five-colored stones made into vessels and dishes, and asserted to be identical with the "strange stones" (*kuai shi* 怪石) mentioned in the Tribute of Yü.⁵ This stone of Lai-chou is well

¹ 佷山北溪水所經皆石山略無土岸。其水淺處多五色石 (*P'ei wên yün fu*, Ch. 100 A, p. 16).

² Ch. B, p. 5^b (edition of *Chi pu tsu chai ts'ang shu*).

³ The latter is found in the water or sandy soil of the district Liu-ho 六合, in the prefecture of Kiang-ning, province of Kiang-su. According to Tu Wan's description, this agate is either a pure white or five-colored, the latter variety being characterized by the same attributes as the stone of Sung-tse; it is locally used for the carving of Buddhist images.

⁴ *P'ei wên yün fu*, Ch. 100 A, p. 16.

⁵ LEGGE, *Chinese Classics*, Vol. III, pp. 102, 104; COUVREUR, *Chou king*, p. 67; compare *Ts'ien Han shu*, Ch. 28 A, p. 1_b. Legge remarks that the "strange stones" are very perplexing to the commentators, and that Ts'ai gets over the difficulty by supposing they were articles indispensable in the making of certain vessels, and not curiosities, merely to be looked at. The above identification seems to me very plausible; on account of its numerous shades and curious designs, in which the imagination of the Chinese sees grotesque scenery, the soapstone of Lai-chou could well have merited the name "strange or supernatural stone."

known to us; it is a variety of agalmatolite or soapstone which is still carved by the Chinese into a hundred odds and ends and worked up into soap, the stone being powdered, and the powder being pressed into forms.¹ Its tinges are manifold and very pleasing, and are therefore capable of artistic effects. The Field Museum owns several albums of the K'ien-lung period, containing pictures (人物) entirely composed of Lai-chou stone of diverse colors, neatly cut out and mounted. The stone being very soft, carving is comparatively easy.²

We accordingly note that in post-Christian times the "five-colored stone" has been identified by the Chinese with a variety of either agate or soapstone. This certainly does not mean at the outset that the stone of the same designation attributed by tradition to times of great antiquity must be identical with one or the other; the ancient name *wu sê shi*, whatever it may have conveyed in its origin, may simply have been transferred to certain kinds of agate and soapstone in comparatively recent periods. This stricture being made, however, there remains a great deal of probability that the five-colored stone of Nü-kua, after all, was nothing else; there is, at least, no valid reason why it should have been something else.³ To this interpretation, Forke might object that in the aforesaid passage of Wang Ch'ung the question is not of the melting of five-colored stones, as in the tradition of Nü-kua, but of the melting of five

¹ F. v. RICHTHOFEN, *Schantung*, pp. 199—200; A. WILLIAMSON, *Notes on the Productions of Shan-tung* (*J. China Branch R. As. Soc.*, Vol. IV, 1868, p. 69); BECHER, *Notes on the Mineral Resources of Eastern Shan-tung* (*ibid.*, Vol. XXII, 1888, p. 37); A. FAUVEL, *The Province of Shantung* (*China Review*, Vol. III, 1875, p. 375).

² It is described in the *Fün lin shi p'u*, Ch. B, p. 1^b.

³ T. DE LACOUPERIE (*Toung Pao*, Vol. II, p. 242) based his theory of five-colored stones on certain geological conditions of Shan-si Province, where, according to A. Williamson, the strata of some hillsides are clearly marked from base to summit, the many-colored clays presenting all the hues of the rainbow. This would not be so bad if the Chinese accounts really spoke of clay; but they obstinately insist on stones, and stone and clay were strictly differentiated notions also to the ancient Chinese.

single stones, and that consequently the aspect of the problem is thus modified; this objection, however, could not be upheld. The solution of the problem is furnished by Wang Ch'ung himself. In two passages of his work, as already pointed out, he himself narrates the tradition regarding Nü-kua, and his mending of the sky by means of five-colored stones. At the end of the chapter,¹ in which he subjects the story to a lengthy discussion, scorning it with ruthless sarcasm, he suddenly changes his phraseology, and speaks of "the repairing of the sky by means of five kinds of stones, which may have worked like medicinal stones in the healing of disease."² Consequently in the diction of the author the two terms "five-colored stone" (*wu sé shi*) and "five stones" (*wu shi*) are interchangeable variants relating to the same subject-matter. It is therefore evident beyond cavil that the passage concerning the fire-apparatus, where the fusing of five stones is mentioned, likewise implies a literary allusion to the Nü-kua legend, and refers to exactly the same affair. If glass is not involved (nor can it be intended) in the Nü-kua legend, it cannot, accordingly, be sought for either, as alleged by Forke, in this passage of Wang Ch'ung.

The question now remains to be answered, Why does Wang Ch'ung bring stones on the tapis to describe an instrument which, judging from all other Chinese records, was a metal mirror? We know that the ancient Chinese possessed mirrors of stone. HIRTH³ has indicated a jade mirror found in A.D. 485 in an ancient tomb near Siang-yang in Hu-pei Province, which the polyhistor Kiang Yen (443—504) stated to date from the time of King Süan (827—782 B.C.). The *Yün lin shi p'u*⁴ mentions two localities where stone material fit for mirrors was quarried, — Mount Wu-ki 涪溪山, in the district

¹ FORKE, *Lan-héng*, pt. 1, p. 252.

² This passage is quoted also in *P'ei wén yün fu*, Ch. 100 A, p. 16.

³ *Chinese Metallic Mirrors (Boas Anniversary Volume, p. 216).*

⁴ Ch. c, p. 9.

of K'i-yang 祁陽, prefecture of Yung-chou 永州, province of Hu-nan, the stone slabs of which, several feet wide, of deep blue (or green) hue, could reflect objects at a distance of several tens of feet; and the district of Lin-ngan 臨安, in the prefecture of Hang-chou 杭州, province of Chê-kiang. In Su-chou, such stone mirrors, usually carved from Yün-nan marble (*Ta-li shi* 大理石), are still offered for sale. When we now critically analyze the passage of Wang Ch'ung, we recognize in it a fusion of three different notions, — first, the alleged melting of stones borrowed from the Nü-kua legend; secondly, a recollection of stone mirrors looming up in his mind; and, thirdly, a reminiscence of metal mirrors used in the Chou period (and also subsequently) for securing fire. In a word, his description is a downright literary concoction, pieced together from three different sources; and it is therefore impossible to regard it as an authentic and authoritative source from which any conclusions as to realities may be derived. It can prove absolutely nothing for the elucidation of facts, such as glass, burning-glasses, burning-mirrors, or anything else. Forke's thesis of the alleged priority of the Chinese in the matter of burning-glasses is untenable; and the fact remains, much more solidly founded than assumed by Forke, that the ancients were the first to make use of them.¹

Another weapon, seemingly still more formidable, has been introduced into the discussion by Schlegel. Liu Ngan, commonly known under the name Huai-nan-tse, a member of the imperial family, philosopher and alchemist, who died in 122 B.C., is credited by SCHLEGEL² with the statement that "it is not absolutely necessary

¹ Forke has not clearly discriminated between burning-lenses and burning-mirrors. I hope to devote a monograph to the latter subject with particular reference to the relation of the Greek burning-mirrors to the Chinese. So much may be said here that Greek priority seems to me to be established along this line also.

² *Uranographie chinoise*, p. 142; and *Nederlandsch-Chineesch Woordenboek*, Vol. I, p. 674.

to employ a bright metal plaque, but that a large crystal ball likewise, held toward the sun, can produce fire." Consequently burning-lenses should have been known to the Chinese in the second century B.C. This would indeed be very nice, were it not that Huai-nan-tse never made such an assertion, wrongly attributed to him by Schlegel. Of all that Schlegel makes him say, he has in fact said only the very first sentence, — "When the mirror is held toward the sun, it will ignite and produce fire," — while all the rest of it does not emanate from the philosopher, but from his later commentators. Schlegel, indeed, does not quote Huai-nan-tse's original text, but derives the passage from a recent work, *Liu ts'ing ji cha* 留青日札.¹ We need only refer, however, to Huai-nan-tse's actual text,² to recognize at a glance the real state of affairs. Huai-nan-tse knew only of concave metal mirrors for the production of fire, but nothing whatever about crystal or any other lenses. He repeatedly mentions the former,³ but never the latter, nor does any of his contemporaries, for the reason that lenses did not turn up on the horizon of the Chinese before the beginning of the seventh century A.D.⁴

BURNING-LENSES NOT A CHINESE INVENTION. DEFICIENT KNOWLEDGE OF THE SUBJECT ON THE PART OF THE CHINESE. — China has indeed known lenses, and certain optical properties of them; yet they were not invented by the Chinese, but were received and introduced by them from India. This fact will be established by the investigation to follow. The subject is somewhat complex, and has never been clearly set forth by any author, Chinese or foreign. It is indispensable to penetrate into the primeval sources, and to sift their

¹ A collection of miscellaneous essays by T'ien Yi-hêng, a writer of the Ming period.

² Ch. 3, p. 2 (edition of *Han Wei ts'ung shu*). In the commentary of this edition no reference is made to crystal lenses; their mention is simply an utterance of the author of *Liu ts'ing ji cha*.

³ For instance, Ch. 5, pp. 11, 14; Ch. 6, p. 2^b; Ch. 8, p. 1^b; etc.

⁴ Another argument of Schlegel in favor of early Chinese acquaintance with burning-lenses is discussed below in the paragraph on ice-lenses.

data with critical eyes, as the recent Chinese writers have been unable to cope with the matter properly; at any rate, none of their statements can be accepted without careful examination. Li Shi-chên, the great Chinese authority on physical science in the sixteenth century, who spent a lifetime on the elaboration of his praiseworthy work *Pên ts'ao kang mu*, has summarized his knowledge of optical lenses (*huo chu* 火珠, "fire-pearls") as follows:¹ "The dictionary *Shuo wên* designates them as 'fire-regulating pearls' (*huo-ts'i-chu* 火齊珠).² The Annals of the Han Dynasty style them *mei-hui* 玫瑰, these characters having the sounds *mei hui* 枚回. The Annals of the T'ang Dynasty narrate that 'in the south-eastern ocean there is the Lo-ch'a country 羅刹國 producing fire-regulating pearls, the biggest of these reaching the size of a fowl's egg, and in appearance resembling crystal 水精. They are round and white, and emit light at a distance of several feet. When exposed to the sunlight, and mugwort is placed near, the latter is ignited.' Such lenses are used in the application of moxa, which in this manner is painless.³ At present there are such lenses in Champa (Chan-ch'êng 占城), which are styled 'great fire-pearls of the morning dawn' (*chao hia ta huo chu* 朝霞大火珠). The *Sü Han shu* 續漢書⁴ says that the country of the Ai-lao barbarians⁵ pro-

¹ *Pên ts'ao kang mu*, Ch. 8, p. 18. This notice is an appendix to his account of rock-crystal.

² This translation and its meaning will be explained in the following section. We have no adequate word to cover exactly the meaning of Chinese *chu* 珠, which means not only a "bead" or "pearl," but also a "gem or precious stone," usually of circular shape. Already D'HERBELOT (*Bibliothèque orientale*, Vol. IV, p. 398) has explained correctly these various shades of meaning.

³ This sentence is not contained in the T'ang Annals, but is Li Shi-chên's own statement. For explanation see below.

⁴ A continuation of the official history of the Han dynasty, written by Sie Ch'êng 謝承 of the third century.

⁵ 哀牢夷. These tribes (their Chinese designation is preserved in the name "Laos") formed the Shan kingdom, first appearing in history during the first century of our era, in the present territory of Sze-ch'uan and Yün-nan.

duces stones styled *huo-tsing* 火精 ('fire-essence') and *liu-li* 琉璃. In view of this fact, the term *huo-ts'i* 火齊 is an error for *huo-tsing* 火精; the latter is correct in correspondence with the term *shui-tsing* 水精 ('water-essence,' a name for rock-crystal).¹ It will be seen from the following discussion that this notice is very inexact in detail, and altogether highly uncritical, — a defect for

¹ F. DE MÉLY (*Lapidaires chinois*, p. 60), who has partially translated this text (not from the original, but from a late Japanese cyclopædia), gives wrong characters and transcriptions of the Chinese terms, — *kiu koei* instead of *mei hui* (or *mei hwei*, or *mei kwei*; see farther below), and *ho chai* in lieu of *huo ts'i*. Moreover, the rendering of *huo chu* by "lupe" is inadmissible, as neither the Chinese nor the Indians have ever made use of magnifying-lenses, but both peoples were familiar only with lenses for fire-making. — The term *huo-tsing* is not an error for *huo-ts'i*, as assumed by Li Shi-chên, but denotes a red variety of rock-crystal supposed to attract fire, while the white variety of the same stone attracts water and fire at the same time (*Wu li siao shi*, Ch. 7, p. 13^b); *huo-tsing* and *huo-ts'i*, in fact, refer to different minerals. In the same manner as among the ancients, the speculations of the Chinese concerning the nature of rock-crystal were divided between the opinions that, on the one hand, it was the essence of water (owing to the outward resemblance to ice) and, on the other hand, the essence of fire (because when struck with steel, it yields sparks, or when used as a lens, produces fire). HIRTH (*China and the Roman Orient*, p. 233) is quite right in deriving the former theory from classical lore. I hope to come back to this subject in detail in a series of studies dealing with Chinese-Hellenistic relations. In opposition to PLINY (XXXVII, 9, § 23), who takes crystal for a kind of ice due to excessive congelation, found only in regions where the winter snow freezes most intensely (*Contraria huic causa crystallum facit, gelu vehementiore concreto. Non aliubi certe reperitur quam ubi maxime hibernae nives rigent, glaciemque esse certum est, unde nomen Graeci dedere*), DIODORUS SICULUS of the first century B. C. expresses the view that crystal originates from purest water hardened into ice, not by cold, however, but through the powerful effect of solar heat (*Crystallum ex aqua purissima in glaciem indurata coalescere aiunt, non quidem a frigore, sed divini ignis potentia*). The celebrated French Bishop MARBODUS (1035—1123) attacked the glacial theory in his poem *De lapidibus pretiosis* (§ 41) as follows: "Crystallus glacies multos durata per annos, | Ut placuit doctis, qui sic scripsere, quibusdam, | Germinis antiqui frigus tenet atque colorem. | Pars negat, et multis perhibent in partibus orbis | Crystallum nasci, quod non vis frigoris ulla, | Nec glacialis hiems unquam violasse probatur." In China, the same theory was called into doubt by Ts'ao Chao 曹昭 in his *Ko ku yao lun* 格古要論, published in 1387: "Although it is said that many years old ice becomes rock-crystal, this is obviously false in view of the fact that green and red crystals occur in Japan" (多年老冰爲水晶然日本國有青水晶紅水晶則水晶非冰也明矣). — an attempt at scientific thinking.

which Li Shi-chên himself is not solely responsible, but which already adheres to his uncritical predecessors. We note, first of all, that he avails himself indiscriminately of three terms, — *huo chu* ("fire-pearl"), *huo-ts'i-chu* ("fire-regulating pearl"), and *mei-hui*. On a previous occasion I ventured to express doubts of the alleged identity of the former two terms;¹ and it will now be demonstrated that they indeed relate to two different mineral substances associated by the early Chinese accounts with two different traditions. In fact, neither the *Shuo wên* nor the Han Annals speak of burning-lenses; Li Shi-chên, however, is quite correct in tracing them to the Lo-ch'a country, but cites the T'ang Annals wrongly by assigning to them the term *huo ts'i chu* instead of *huo chu*. This text of the T'ang Annals indeed is the first and earliest authentic Chinese account relative to burning-lenses. We note also that Li Shi-chên does not claim any knowledge of them on the part of Wang Ch'ung or Huai-nan-tse; and, as far as I know, there is no Chinese author who would make such a pretension. The various problems raised by the text of the *Pên ts'ao kang mu* will now be discussed in detail.

HUO-TS'I NOT A BURNING-LENS, BUT MICA. — The earliest definition of the "fire-regulating pearl" (*huo ts'i chu* 火齊珠)² that occurs

¹ *Notes on Turquoise in the East*, p. 28.

² HIRTH and ROCKHILL (*Chau Ju-kua*, p. 113) express the opinion that *huo ts'i* appears to be a foreign word, without being able, however, to indicate for which foreign word it might be intended. This supposition is hardly probable, as the phrase *huo ts'i* is good old Chinese, and yields a reasonable sense. It occurs in the ancient Book of Rites (*Lî ki*, chap. *Yüe-ling*, ed. COUVREUR, Vol. I, p. 401; LEGGE's translation, Vol. I, p. 303): "In the second month of winter, orders were given to the grand superintendent of the preparation of liquors to see that the rice and other glutinous grains be all complete, etc., that the water be fragrant, that the vessels of pottery be good, and that the regulation of the fire (*huo ts'i* 火齊) be right." The term *huo ts'i chu*, accordingly, is very well fitted to signify "a pearl (or gem) used in regulating fire." Indeed, the term *huo-ts'i*, as shown farther on, has been employed for a mineral indigenous in China, and belonging to the mica group, prior to her contact with India; we hear, for instance, of screens (*Shi i ki*, Ch. 5, p. 6; ed. of *Han Wei ts'ung shu*), couches, and finger-rings of *huo-ts'i*, of native manufacture (*ibid.*, Ch. 8, p. 3). This subject is not pursued here any further, as it will be treated by the writer in a special monograph on mica.

in the Annals of China is embodied in the History of the Liang Dynasty,¹ which enumerates it among the products of Central India, and describes it as follows: "Huo-ts'i, in its appearance, is like the mica of China,² with a tinge like that of purple gold, and of intense brilliancy. Pieces split off from it are as thin as the cicada's wings; when joined together again, they are like doubled silk gauze."³ This text, however, is not peculiar to the two Annals, but is

¹ *Liang shu*, Ch. 54, p. 7^b. The Liang dynasty covers the period from 502 to 556. Its history was compiled by Yao Se-lien in the first half of the seventh century. The same text is found also in *Nan shi* (Ch. 78, p. 7). The latter work, comprising the history of China from 420 to 589, was elaborated by Li Yen-shou in the seventh century.

² In Chinese *yün-mu* 雲母 (literally, "cloud-mother"). On the basis of a specimen obtained from China, *yün-mu* was identified with mica by E. BIOT (in PAUTHIER-BAZIN, *Chine moderne*, Vol. II, p. 558), who also rejected Rémusat's interpretation of this term as "mother-o'-pearl" (this meaning is erroneously given by PALLADIUS, *Chinese-Russian Dictionary*, Vol. II, p. 543). He pointed out seven varieties bearing different names. Under the same name, *yün-mu*, the different varieties of mica have well been described by GEERTS (*Produits de la nature japonaise et chinoise*, Vol. II, pp. 426-433); while F. PORTER SMITH (*Contributions toward the Materia Medica of China*, p. 210) mistook *yün-mu* for talc, though describing mica under that title. G. SCHLEGEL (*T'oung Pao*, Vol. VI, 1895, p. 49) has contributed to the subject a few notes which are rather inexact; only his erroneous view that *yün-mu* is a modern term, may here be pointed out. As in many studies of orientalists we meet the phraseology "mica or talc," it cannot be strongly enough emphasized that mica and talc are fundamentally different minerals; and it is even difficult to see how they could ever be confounded. The word *yün-mu* has been adopted for the designation of mica in the modern scientific mineralogy of China and Japan (see, for instance, *Journ. Geol. Soc. of Tokyo*, Vol. XIX, 1912, p. 413), while talc is *hua shi* 滑石 or *fei-tsoo shi* 肥皂石; the identification of *yün-mu*, therefore, is absolutely certain. The Chinese name arose in consequence of the belief that this mineral forms the basis in the origin of the clouds; that is, strictly speaking, the clouded appearance of the mineral was instrumental in inspiring this popular belief. The Sanskrit designation for mica is *adhra*, a word appearing as early as the fifth century in the Bower Manuscript (A. F. R. HOERNLE, *The Bower Manuscript*, pp. 11, 117). This word means literally "cloud, atmosphere," and thus presents a curious counterpart of the Chinese designation for the same mineral, *yün-mu* ("cloud-mother"). The Chinese alchemists took powdered mica internally in order to insure long life; and when placed in the grave, it was believed to have the effect of preserving the body from decay.

火齊狀如雲母。色如紫金。有光耀。別之則薄如蟬翼。積之則如紗縠之重沓也。

encountered as early as the third century in the *Nan chou i wu chi* 南州異物志 ("Account of Remarkable Objects in the Southern Provinces"), by Wan Chên 萬震,¹ where it is prefaced by the statement that *huo-ts'i* comes from, or is produced in, the country of India;² and it is this work which has doubtless served as a source to the annalist. The brief description of the mineral is perspicuous enough to enable one to recognize in it mica, — a group of minerals that crystallize in the monoclinic system, and consist essentially of aluminum silicate. The striking characteristic of all species is a highly perfect basal cleavage, by which the crystals may be split into the thinnest films (that is, the cicada wings of the Chinese). It is to this property, and to the highly elastic nature of the lamellæ (by which mica is distinguished from the flexible, foliated, but inelastic mineral, talc), as well as to the fact that it is able to withstand high temperatures and is a bad conductor of electricity, that mica owes its commercial value.³

It was not in India, however, that the Chinese acquainted themselves with mica for the first time. Mica is indigenous in many places of China; and a contemporary of Wan Chên, Chang Pu 張勃, the author of a geographical description of the kingdom of Wu,⁴ mentions the mineral "*huo-ts'i*, which is like *yün-mu*, as occurring

¹ According to *Sui shu* (Ch. 33, p. 10), Wan Chên lived in the time of the Wu dynasty (third century).

² 火齊出天竺國 (*T'ai p'ing yü lan*, Ch. 809, p. 2). The only variant encountered in this text is in the fourth sentence: 節如蟬翼 別之 etc., as above. The *Pên ts'ao kang mu* (Ch. 8, p. 18), in the notice of *liu-li*, quotes the same text from the work *I wu chi*, which says that the stone is a product of all countries of southern India.

³ Compare the excellent article "Mica" in G. WATT'S *Dictionary of Economic Products of India*, Vol. v, pp. 509—513 (also as separate reprint), where its uses, geological and geographical distribution, as well as mining and trade in India, are fully discussed.

⁴ *Wu lu ti li chi* 吳錄地理志 (see BRETSCHNEIDER, *Bot. Sin.*, pt. 1, No. 1043).

in the district Si-küan.¹ It is composed of many layers, and can accordingly be split. It is of yellow color, resembling gold.”² This, again, is an unmistakable characterization of mica, and of that variety known to us as golden mica (*or de chat*).³ We note that a kind of mica was known in China under the name *huo-ts'i*, and that the Chinese merely rediscovered this particular species in India; the term *huo-ts'i*, therefore, cannot be the rendering of a Sanskrit word, and such a Sanskrit name as might come into question, indeed, does not exist.

Huo-ts'i are referred by the Chinese also to some countries located in south-eastern Asia. In the year 519, Jayavarman, King of Fu-nan (Cambodja), sent an embassy to China, and offered pearls of that description, saffron (*yii-kin*), storax, and other aromatics.⁴ In 528 and 535 two embassies arrived in China from a country called Tan-tan 丹丹, and *huo-ts'i* pearls or beads were included among the tribute-gifts of the latter mission.⁵ Very little is known about this country, and its identification is not ascertained. At the time of the T'ang dynasty (618—906) it is mentioned again as being situated south-east of the island of Hai-nan, and west of the

¹ As the kingdom of Wu comprised the present territory of Kiang-su, Chê-kiang, and parts of An-hui, this locality must have been within the boundaries of these provinces.

² 西倦縣有火齊如雲母。重沓可開。黃似金 (Tai ping yü lan, Ch. 809, p. 2). The coincidence of the terms used in this text and the *Nan chou i wu chi* is notable.

³ Now termed in Chinese *kin sing shi* 金星石 (“gold star stone”) or *kin tsing shi* 金精石. See GEERTS, *Produits de la nature japonaise et chinoise*, Vol. II, p. 430; D. HANBURY, *Science Papers*, p. 219; and F. PORTER SMITH, *Contributions toward the Materia Medica of China*, p. 148, who mentions Kiang-nan as a locality where it occurs; this is probably identical with that mentioned in the above Chinese work. The Imperial Geography (*Ta Ts'ing i t'ang chi*, Ch. 244, p. 11) mentions the district of Tê-hua (forming the prefectural city of Kiu-kiang, province of Kiang-si) as producing mica (*yün mu*).

⁴ *Liang shu*, Ch. 54, p. 5^b; or *Nan shi*, Ch. 78, p. 4 (compare PELLIOU, *Bull. de l'École française*, Vol. III, p. 270).

⁵ *Liang shu*, *ibid.*

country To-lo-mo 多羅磨, which is otherwise unknown to us.¹ G. SCHLEGEL,² in a discussion of this passage of the Liang history, without adducing any evidence, rendered the term *huo-ts'i* by "Labrador feldspat," which is an arbitrary and unwarranted opinion.³ Both Fu-nan and Tan-tan, this much is certain, were countries in the sphere of influence of Indian civilization; and in the same manner as Fu-nan received diamonds in consequence of its lively intercourse with India,⁴ so also its *huo-ts'i* gems were undoubtedly derived from the same source.

Aside from India, Fu-nan, and Tan-tan, *huo-ts'i* are listed in the Chinese Annals also among the products of Persia; that is, Persia in the epoch of the Sassanian dynasty.⁵ Since Persia was then in close relations with India, it is highly probable that the *huo-ts'i* of Persia, like many other products attributed to the country by the Chinese,⁶ also hailed from India. We shall revert once again to Persia when discussing the term *mei-hui*.

There is not a single ancient Chinese account that speaks of the use of burning-lenses in regard to *huo-ts'i*.⁷ The only purpose to

¹ *Tang shu*, Ch. 222 B, p. 4 (compare PELLLOT, *Bull. de l'École française*, Vol. IV, p. 284).

² *T'oung Pao*, Vol. X, 1899, p. 460.

³ Schlegel's view that the country Tan-tan should be sought for on the Malay Peninsula, and be identified with the mysterious Dondin, placed by Odoric of Pordenone of the fourteenth century between Ceylon and China, has been refuted by PELLLOT (*l. c.*).

⁴ India traded diamonds with Ta Ts'in, Fu-nan, and Kiao-chi (*T'ang shu*, Ch. 221 A, p. 10^b).

⁵ *Pei shi*, Ch. 97, p. 7^b; *Wei shu*, Ch. 102, p. 5^b; *Sui shu*, Ch. 83, p. 7^b.

⁶ HIRTH and ROCKHILL, *Chau Ju-kua*, p. 16.

⁷ The conclusion of some Chinese authors that *huo-ts'i* are burning-lenses may have been prompted partially by the report of a mica mirror (*huo ts'i king*) contained in the *Shi i ki* (Ch. 3, p. 6^b; ed. of *Han Wei ts'ung shu*). This mirror, three feet in width, is alleged to have been sent as a gift by a country styled K'ü-sü 渠胥, at the time of the Emperor Ling of the Chou dynasty (571—545 B.C.). In a dark room, objects were visible in it as in the daytime; and when words were spoken in the direction of the mirror, an echo sounded from it as answer. HIRTH (*Boas Anniversary Volume*, p. 228) sees in this mirror a practical demonstration of the theory of sound-reflection, coupled

which the latter was turned was for making lanterns transparent and durable. This confirms the fact that *huo-ts'i* is mica, for the earliest application of it in India and China was in windows and lanterns.¹ Muscovite, a variety of mica, is still employed for lamp-chimneys, as fire-screens in the peep-holes of furnaces, and as screens in the laboratory, for observing the processes in a highly heated furnace without suffering from the intense heat. It is thus clear why the Chinese called this mineral *huo-ts'i* "fire-regulating;" and it is also clear that, since mica cannot by any means be made into a burning-lens, the alleged identity of *huo-ts'i* with the burning-lens styled *huo-chu* is absolutely wrong. Only the fact that the word "fire" forms the first element in the names of both minerals suggested this hypothesis to the Chinese philologists. But there is a fundamental difference in characterizing the two by the attribute "fire." In mica it refers to that phenomenon known to us as asterism, — the exhibition of a starlike reflection, which occurs also in sapphire, chiefly displayed by some phlogopites when a candle-flame is viewed through a sheet of the mineral, — and the frequent use of the substance for windows, as remarked by Watt, may have facilitated the observation of this peculiar property. The fact that the Chinese were perfectly aware of it has already been demonstrated by the reference to the mica windows in the palaces of Lo-yang; and there is another similar report in the Records of Kuang-tung Province,² according to which the mica of

with that of light-reflection. The text itself, like the book from which it is taken, is apocryphal. The assigning of it to the Emperor Ling is a gross anachronism, and nothing is known about the country K'ü-sü.

¹ Windows of mica are mentioned in a *Description of the Palaces of Lo-yang* (*Lo-yang kung tien ki* 洛陽宮殿記; *T'ai ping yü lan*, Ch. 308). They spread a dazzling brilliancy in the sunlight. Also fans were made from the same substance by Shi Hu 石虎 (mentioned in his work *Ye chung ki* 鄴中記; see BRETSCHNEIDER, *Bot. Sin.*, pt. 1, No. 1079).

² *Kuang chou ki* 廣州記, by P'ei Yüan 裴淵, who lived under the Tsin dynasty (265—419); see BRETSCHNEIDER, *Bot. Sin.*, pt. 1, No. 377.

the district of Tsêng-ch'êng, when struck by the sunlight, emits a brilliant light.¹

LIU-LI AND LANG-KAN NOT BURNING-LENSES. — We find also the opinion heralded by Li Shi-chên that the stone *liu-li* 琉璃 (Sanskrit *vaidūrya*) is identical with the *huo-ts'i* gem. This notion goes back to Ch'ên Ts'ang-k'i 陳藏器, who lived during the first part of the eighth century at San-yüan (in the prefecture of Singan, Shen-si Province), and who is the author of the *Pen ts'ao shi i* 本草拾遺. This work seems to be lost; but extracts of it are preserved in the later works on natural history, notably in the *Chéng lei pén ts'ao* 證類本草 of the year 1108, and in the *Pén ts'ao kang mu*. In both works he is quoted as saying that, according to the dictionary *Tsi yün* 集韻, *liu-li* is the same as the gem *huo-ts'i*. This work, of course, is not the *Tsi yün* which was begun in 1034 and completed in 1039,² but the *Tsi yün* or *Yün tsi* by Lü Tsing 呂靜 of the Tsin dynasty (265—419).³ We are here confronted with a purely philological opinion of a lexicographer, which is hardly founded on a personal examination of the objects concerned,⁴ nor is it very likely that Sanskrit *vaidūrya* ever referred to a variety of mica.

增城縣有雲母向日炤之光耀 (*T'ai p'ing yü lan*, Ch. 808). — The introduction of plate-glass has now supplanted the use of mica in Eastern Asia; but some curious survivals of it still occur in Tibet. The Tibetans manufacture an abundance of charm-boxes (*gan*), some of large dimensions in the form of shrines; a window is cut out in the metal surface to render the image in the interior visible. This window is now usually covered with European glass, but also with a transparent sheet of mica. Ornaments of mica are still employed by the women in the territory of the Kuku-nör for the decoration of their fantastic head-dresses.

² WATERS, *Essays on the Chinese Language*, p. 60.

³ See the Catalogue of Sui Literature (*Sui shu*, Ch. 32, p. 22; and WATERS, *l. c.*, p. 40). *T'ai p'ing yü lan* (Ch. 809, p. 2) quotes the same definition from the dictionary *Yün tsa* 韻雜, which presumably is a misprint for *Yün tsi* 韻集.

⁴ This discussion bears out the reasons which induced F. PORTER SMITH (*Contributions toward the Materia Medica of China*, p. 120) to identify *huo-ts'i* with lapis lazuli, as he took *liu-li* for the latter and encountered the equation of *huo-ts'i* with *liu-li*.

As the term *liu-li* refers to certain varieties of rock-crystal¹ and to certain vitreous products, it would be possible in theory that burning-lenses were made from this substance; but no such instance is on record. There is, however, an isolated case in which a specular lens of this material is in question.

In the year 499, the Buddhist monk Hwei Shên 慧深 returned to China under the pretence that he had visited a marvellous island in the farthest east, called Fu-sang 扶桑, and made a glowing report of its wonders. It is well known that a number of European and American scholars sought this alleged country Fu-sang in Mexico or somewhere else in America, and pretended that this continent had been discovered by the Chinese nine centuries before Columbus. Others, of a more sober trend of mind, localized Fu-sang on Sachalin or on islands near Japan. But even this moderate attitude rests on a cardinal error, for Fu-sang, as described by Hwei Shên, is not a real country at all, but a product of imagination, a geographical myth, composed of heterogeneous elements, as will be shown by me elsewhere. In this connection Fu-sang is of interest to us, as the earliest Chinese mention of a specular lens is associated with it. In the beginning of the sixth century envoys of Fu-sang are alleged to have appeared in China, "offering as tribute a precious stone for the observation of the sun (*kuan ji yü* 觀日玉), of the size of a mirror, measuring over a foot in circumference, as transparent as rock-crystal (*liu-li*); looking through it in bright sunlight, the palace-buildings could be very clearly distinguished."² The event

¹ It would be preferable to use the general term "quartz," as it is impossible to determine in each and every case what kind of crystal is intended.

² 扶桑國使使貢觀日玉。大如鏡。方圓尺餘。明澈如琉璃。映日以觀日 (variant: 見) 中宮殿皎然分明 (*T'ai p'ing yü lan*, Ch. 805, p. 10). This text is derived from the book *Liang se kung tse ki*, 梁四公子記, "Memoirs of the Four Lords of the Liang Dynasty

of the embassy here alluded to is apocryphal, for it is not on record in the official Annals of the Liang Dynasty; the country Fu-sang itself is an imaginary construction. Moreover, the work which contains this story, and which consists of conversations held by the four Lords¹ with the Emperor Wu of the Liang dynasty (502—549) has a decided tendency toward the wondrous, and teems with fables derived from the West. Notwithstanding, all this does not detract from the value of this first account of a specular lens, through which objects could plainly be beheld. I think that SCHLEGEL² was not so very wrong in lending expression to the opinion that this "precious stone for the observation of the sun" was a rock-crystal.

In his book (happily now forgotten) *Fusang or the Discovery of America by Chinese Buddhist Priests in the Fifth Century* (1875) CH. G. LELAND has utilized also this notice in support of his Fusang-American hypothesis, and has tried to establish an analogy between the observation glass of the Chinese account and the burning-mirrors of metal which the ancient Peruvians are alleged to have employed for kindling their sacred fire. BRETSCHNEIDER³ who banished the nightmare of Leland with as much critical acumen and as a solid fund of information refuted this particular point only by discounting the credibility of the Chinese source in question.⁴

(502—556)," written by Chang Yüe 張說 (667—730), statesman, poet, and painter (GILES, *Biographical Dictionary*, p. 51).

¹ They were Hwei-ch'uang 翬闕, Wan-kie 韋僊杰, Wei-t'uan 魏黃耑, and Chang-ki 仇啟.

² *T'oung Pao*, Vol. III, 1892, p. 139.

³ *Über das Land Fu Sang (Mitt. d. Ges. Ostasiens*, Vol. II, No. 11, 1876, pp. 1—11).

⁴ He erroneously styled the work "the memoirs of a certain Liang sze kung." In his *Botanicon Sinicum* (pt. I, p. 169) the title is correctly explained. In an old catalogue of books from the twelfth century, Bretschneider comments, this work is described as totally unreliable, as the author narrates mostly wondrous and incredible stories. This is merely a conventional Chinese mode of literary criticism. The wondrous stories of this book are of incalculable historical value to us, as many of them are exact reproductions of western legends.

This point of view is unnecessary. We certainly do not have to believe in the embassy from Fu-sang, which is not confirmed by the Annals; the instrument, however, described in the report cannot be a personal invention of Chang Yüe, the author of that work, but surely is a reality. It doubtless was a lens which permitted to see the distant palace-buildings with greater distinction; yet it was not a burning-lens, and the comparison drawn by Leland is far from the point. Moreover, the alleged burning-mirrors of the Peruvians existed merely in the imagination of Garcilaso de la Vega, whose fantasy has already been exploded by E. B. TYLOR.¹

It is possible to trace with some degree of probability the real origin of that lens fancifully associated with the mythical land Fu-sang. The work *Liang se kung tse ki* that contains this account offers the following interesting text: "A large junk of Fu-nan which had hailed from western India arrived (in China) and offered for sale a mirror of a peculiar variety of rock-crystal (碧玻璃鏡),²

¹ *Researches into the Early History of Mankind*, pp. 250—253 (New York, 1878).

² G. PAUTHIER (*L'inscription de Si-nyan-fou*, p. 31, Paris, 1858), who first called attention to this text, was quite correct in explaining the term *p'o-li* as "rock-crystal." PELLIOT (*Bull. de l'École française*, Vol. III, p. 283) accepts *p'o-li* in this passage in the sense, commonly adopted, of "glass," while admitting that it etymologically corresponds to Sanskrit *sphaṭika*. The latter, however, means "rock-crystal," and in my opinion the Chinese word *p'o-li*, derived from it, in the greater number of ancient texts, has the same significance. Evidence based on other texts will be produced farther below; here we discuss only the text under consideration. For two weighty reasons it is impossible to regard the mirror mentioned in the *Liang se kung tse ki* as a glass mirror. First,—the story of the merchants, which is an echo of the Western legend of the Diamond Valley, reveals the fact that the question is of a precious stone, not of glass; among the numerous versions of this legend, there is not one that speaks of glass, but all of them are unanimous in mentioning hyacinths, diamonds, or precious stones in general. A plain glass mirror, most assuredly, would not have been priced so highly, nor have caused such a sensation, nor have been linked with a legend of that character. Second,—glass mirrors were not yet invented at that time in the West, and for this reason the conclusion that they should have been known in India and Fu-nan during the sixth century seems to me very hazarded. True it is that HIRTH (*Chinese Metallic Mirrors*, *Boas Ann. Vol.*, p. 219), who also regards this mirror from Fu-nan as being of "green glass" (see, however, also the following footnote), and who wonders at the incredible price solicited for it, supports his theory by

one foot and four inches across its surface, and forty catties in weight. It was pure white and transparent on the surface and in the interior, and displayed many-colored things on its obverse. When held against the light and examined, its substance was not discernible.¹ On in-

the statement that the ancients were acquainted with glass mirrors. This argument, however, is not valid; we have to study only the famous and ingenious treatise of J. BECKMANN (*Beiträge zur Geschichte der Erfindungen*, Vol. III, particularly pp. 302—335; an English translation of this monumental work was published in 1814 by W. JOHNSTON) to become thoroughly convinced of the baselessness of Hirth's claim; and the result of Beckmann, who wrote in 1792, is upheld both by classical philology (MORGAN, *Harvard Studies in Classical Philology*, Vol. I, 1890, pp. 50—51) and by the modern history of technology (FELDHIAUS, *Technik der Vorzeit*, col. 1044). The plain fact remains that real glass mirrors in our sense did not come up in Europe before the latter part of the thirteenth century, and that they did not exist in classical antiquity. — I do not deny, of course, that in a later period the term *p'o-li* assumed the meaning of "glass;" the exact date remains to be ascertained.

¹ HIRTH and ROCKHILL (*Chau Ju-kua*, p. 228), who have translated merely the beginning of this text on the basis of an incomplete quotation in *T'u shu tsi ch'eng*, render this sentence, "Objects of all kinds placed before them [the mirrors] are reflected to the sight without one's seeing the mirror itself." Even if this translation were admissible, which I venture to doubt, I am at a loss to understand what it should mean; it even seems to convey the meaning of something that is impossible. The sentence 置五色物於其前 (see the complete text of the passage on p. 202, note 3) cannot be linked with the following 向 etc., which is a new sentence expressing a new idea. This may be inferred also from the text, as quoted in *P'én ts'ao kang nu*, in which the sentence beginning with 置 etc. is omitted, while the sentence beginning with 向 etc. is completely reproduced. Objects are certainly not placed in front of a mirror to be seen, but man wants to behold himself or objects in a mirror. It is obvious that the objects here mentioned were natural designs formed by zones of various colors in the stone. As they were not acquainted with the complete text, as handed down in *T'ai p'ing yü lan*, Hirth and Rockhill understand that the junks of Fu-nan habitually sell such mirrors to the Chinese. Our story renders it clear that only an isolated instance comes into question, and that this particular, unusual mirror could not even be disposed of in China. The *Liang se kung tse ki* is not a work on commercial geography summarizing general data, but is a story-book narrating specific events. We have in the present case not a description, but a narrative. For the rest, however, the notes contributed by Hirth and Rockhill on the history of glass are very interesting and valuable, though many problems connected with this difficult subject still remain unsolved. Hirth's opinion, that *pi-p'o-li* should be regarded as a word-formation prompted by analogy with *pi-liu-li*, is very plausible. Our text indeed renders this conception almost necessary, as the word *pi* cannot be taken here in the sense of "green," the substance of the mirror being described as white and transparent.

quiry for the price, it was given at a million strings of copper coins. The Emperor ordered the officials to raise this sum, but the treasury did not hold enough. Those traders said, 'This mirror is due to the action of the Devarāja of the Rūpadhātu.¹ On felicitous and joyful occasions, he causes the trees of the gods² to pour down a shower of precious stones, and the mountains receive them. The mountains conceal and seize the stones, so that they are difficult to obtain. The flesh of big beasts is cast into the mountains; and when the flesh in these hiding-places becomes so putrefied that it phosphoresces, it resembles a precious stone. Birds carry it off in their beaks, and this is the jewel from which this mirror is made.' Nobody in the empire understood this and dared pay that price."³

The story connected in this report with the crystal mirror is a somewhat abrupt and incomplete version of the well-known legend of the Diamond Valley, the oldest hitherto accessible Western version

¹ 色界天王 ("the Celestial King of the Region of Forms"). The Rūpadhātu is the second of the three Brahmanic worlds. The detailed discussion of this subject on the part of O. FRANKE (*Chinesische Tempelinschrift*, pp. 47—50) is especially worth reading. The Devarāja here in question is Kubera or Vaiçravaṇa, God of Wealth, guarding the northern side of the world-mountain Sumeru and commanding the host of the aerial demons, the Yaksha.

² 天樹. This term corresponds to Sanskrit *devataru*, a designation for the five miraculous trees to be found in Indra's Heaven (compare HOPKINS, *Journ. Am. Or. Soc.*, Vol. xxx, 1910, pp. 352, 353).

³ 梁四公記。扶南大船從西天竺國來賣碧玻瓈鏡面廣一尺四寸重四十斤。內外皎潔置五色物於其前。向明視之不見其質。問其價豹錢百萬貫文。帝令有司算之以府庫當之不足。其商人言。此色界天王。有福樂事天樹大雨雨衆寶山納之。山藏取之難得。以大獸肉投之。藏中肉爛類寶一。鳥銜出而此寶焉。舉國不識無敢酬其價者 (*T'ai p'inyü lan*, Ch. 808, p. 6).—The narrative is obscure in omitting to state that the jewels adhere to the flesh which is devoured by the birds.

of which is contained in the writings of EPIPHANIUS, Bishop of Constantia in Cyprus (*circa* 315—403).¹ Again, it is the author of that curious work, *Liang se kung tse ki*, who has preserved to us the earliest Chinese form of this legend which strikingly agrees with the story of Epiphanius. This text is worded as follows: "In the period T'ien-kien (502--520) of the Liang dynasty, Prince Kie of Shu (Sze-ch'uan) paid a visit to the Emperor Wu,² and, in the course of conversations which he held with the Emperor's scholars on distant lands, told this story: 'In the west, arriving at the Mediterranean,³ there is in the sea an island of two hundred square miles (*li*). On this island is a large forest abounding in trees with precious stones, and inhabited by over ten thousand families. These men show great ability in cleverly working gems,⁴ which are named for the country Fu-liu 拂林.⁵ In a northwesterly direction from

¹ *Epiphaniï opera*, ed. DINDORF, Vol. IV, p. 190 (Leipzig, 1862). On the basis of these new Chinese sources, I have treated the history of this legend in detail in a study on the diamond (unpublished manuscript of the writer), and therefore do not pursue the subject further on this occasion.

² He was the first emperor of the Liang dynasty and lived from 464 to 549 (GILES, *Biographical Dictionary*, p. 285).

³ *Si hai* 西海 (the "Western Sea"). Compare HIRTH, *Journ. Am. Or. Soc.*, Vol. XXXIII, 1913, p. 195.

⁴ This must be referred to the cutting and engraving of antique intaglios (gems in the sense of Latin *gemma*).

⁵ The same mode of writing (林 instead of the later 菽) as that encountered by CHAVANNES (*T'oung Pao*, 1904, p. 38) in a text of 607, extracted from the *Ts'e fu yüan kuei*. The same way of writing occurs also in *Yu yang tsa tsu* and in a poem of the T'ang Emperor T'ai-tsung (*P'ei wên yün fu*, Ch. 27, p. 25). As our text speaks of a forest of jewelled trees, a popular interpretation of the name Fu-lin apparently is intended here, "forest" (林) of the jewels being read into Fu-lin; as if it were "forest of Fu." We are here confronted with the earliest allusion in Chinese records to the country Fu-lin, antedating our previous knowledge of it by a century, Hirth having traced the first appearance of the name to the first half of the seventh century. The reference to the period T'ien-kien (502--520), and the mention of the Liang Emperor Wu, are exact chronological indications which now carry Chinese acquaintance with Fu-lin to the beginning of the sixth century. This result perfectly harmonizes with the view expressed by PELLIER (*Journal asiatique*, Mars-Avril, 1914, p. 498), that the name Fu-lin appears with certainty about 550, and that it is possibly still older.

the island is a ravine hollowed out like a bowl, more than a thousand feet deep. They throw flesh into this valley. Birds take it up in their beaks, whereupon they drop the precious stones. The biggest of these have a weight of five catties.' There is a saying that this is the treasury of the Devarāja of the Rūpadhātu."¹ This is not the occasion to discuss the history and development of this interesting legend in connection with its Arabic and subsequent Chinese parallels; this will be done by me in another place. Suffice it to say for the present that the Chinese version is an exact parallel to that of Epiphanius, that it antedates all Arabic versions, that it represents a purer form than the earliest Arabic text in the *lapidarium* of Pseudo-Aristotle, and that it was transmitted to China directly from Fu-lin. I have here fallen back on these two texts of the *Liang se kung tse ki* to introduce the reader to the mental horizon of its author, Chang Yüe, and thus to secure a basis for judging the *raison d'être* of the specular lens ascribed by him to an embassy from Fu-sang. It was a plausible *a priori* supposition that this instrument must have been one of Western manufacture; and being now familiar with the outfits and tools of the workshop of Chang Yüe, who absorbed traditions of Fu-nan, India, and Fu-lin, we may well infer that the alleged Fu-sang lens was really a

梁四公記。梁天監中有蜀杰公謁武帝嘗與諸儒語及方域。西至西海海中有島方二百里。島上有大林。林皆寶樹中有萬餘家。其人皆巧能造寶器所謂拂林國也。島西北有坑盤坳深千餘尺。以肉投之。鳥銜寶出大者重五斤。彼云是色界天王之寶藏 (*T'u shu tsi ch'ang*, section on national economy 321, 寶貨, *tsung pu ki shi*, p. 5). — The last sentence, of course, is not an element inherent in the story, as it came from Fu-lin, but is an interpolation of the Chinese author Chang Yüe, taken from the narrative which the traders of Fu-nan had overheard in India.

product of Syria (Fu-liu) and reached China possibly by way of India and Cambodja (Fu-nau), in the same manner as the costly mirror of rock-crystal.¹

A product termed *lang-kan* 琅玕 is identified with *huo-ts'i* by Su Kung 蘇恭 of the T'ang period,² who, at the same time defines the former as a kind of *liu-li*. K'ou Tsung-shi 寇宗奭, in his *Pên ts'ao yen i* 本草衍義 of 1116, calls him to task for this wrong statement by observing that *liu-li* is a substance evolved by fire, while *lang-kan* is not, so that the two could not represent identical species. Su Kung's identification has indeed not been adopted by any subsequent Chinese scholar.³

¹ In the writer's proposed Chinese-Hellenistic studies will be found several interesting examples of Hellenistic folk-lore traditions looming up in Fu-nan and thence transmitted to China.

² *Chên-yi lei pên ts'ao*, Ch. 5, fol. 26. Also in a commentary to the dictionary *Ki tsiu pien* 急就篇 (*P'ei wên yün fu*, Ch. 7 A, p. 106 b).

³ *Lang-kan*, in times of antiquity, appears as a mineral, mentioned already in the earliest Chinese document, the tribute of Yü, in the *Shu king* (LEGGE, *Chinese Classics*, Vol. III, p. 127), as a product of the province of Yung-chou; its exact nature cannot be determined, the commentators saying no more than that it was a stone used for beads; Legge's explanation that possibly it was lazulite or lapis lazuli, is purely conjectural. The *Shuo wên* defines *lang-kan* as a stone resembling jade; and the *Erh ya* localizes it in the K'un-lun. The *Pie lu* 別錄 assigns the stone to P'ing-tsê 平澤 in Shu 蜀 (Sze-ch'uan). *Wei lio*, *Hou Han shu*, *Liang shu*, and *Wei shu* (HIRTH, *China and the Roman Orient*, pp. 41, 47, 50, 73) mention *lang-kan* among the products of Ta Ts'in; no explanation of its significance with reference to these passages is on record. We find *lang-kan* also in Kucha (*Liang shu*, Ch. 54, p. 14), in central India (*ibid.*, p. 7 b), and generally in India (*T'ang shu*, Ch. 221 A, p. 10 b). From the T'ang period onward the Chinese naturalists or pharmacists, beginning with Ch'ên Ts'ang-k'ü, describe *lang-kan* as a kind of coral, growing like a tree with root and branches on the bottom of the sea, fished by means of nets, and being reddish, when coming out of the water, but subsequently turning darker. The *Yün lin shi p'u* (Ch. c, p. 9 b) says that it is a stone caught in shallow places near the coast of Ning-po, resembling the genuine coral (*shan-hu*), being white, when coming out of the water, and afterwards turning purple or black. Li Shi-chên objects to the application of the term *lang-kan* to these marine products which, according to him, should be credited with the name *shan-hu*, while the former should be restricted to a stone occurring in the mountains. Compare also SCHLEGEL, *T'oung Pao*, Vol. VI, 1895, p. 58; F. DE MÉLY, *Lapidaires chinois*, p. 56; HIRTH and ROCKHILL, *Chau Ju-kua*, pp. 162, 226. The word *lang-kan* seems to be an onomatopoeic formation descriptive of the

THE MINERALOGICAL TERM MEI-HUI. — Finally we have to discuss the term *mei-hui* 玫瑰, which, according to Li Shi-chên, also should refer to lenses. It first appears in the poem *Tse hiü fu* 子虛賦 of Se-ma Siang ju, who died in 117 B.C., as one of the mineral products of Sze-ch'uan.¹ Kuo P'o (275—324) explains it as a stone bead 石珠; Tsin Pao 晉灼 says that it is identical with *huo-ts'i* beads; and Yen Shi-ku (579—645) reiterates the same, adding that "is is the 'fire-pearl' coming at present from the countries of the south."² These definitions are vague and unsatisfactory, being made by philologists who in all probability had never seen any of the stones in question. Yen Shi-ku errs in identifying *huo-ts'i* with *huo-chu*, and therefore the identification of both with *mei-hui* is presumably wrong also. The dictionary *Shuo wên* (A.D. 123) notes *huo-ts'i* as an equivalent or synonyme of *mei-hui*; as we have shown that the former covers the group of micas, it would follow from this definition, provided it is correct, that *mei-hui* should be a variety of mica, and consequently cannot be a burning-lens.

The term *mei-hui* is listed also in the ancient vocabulary *Ki tsiu chang* 急就章, edited by Shi Yu 史游 under the reign

sound yielded by the sonorous stone when struck (compare the words *lang* 礮, "rumbling of stones, roll of a drum;" and *lang* 朗, "clear, as light or sound;" *lang-t'ang* 朗鐘 is used in Peking as an interjectional expression, imitative of the noise of gongs and drums; in general compare chap. IV of WATTERS, *Essays on the Chinese Language*). This point of view would account for the fact that the name *lang-kan* was transferred from a stone to a coral; for Tu Wan, in his *Yün lin shi p'u* (l. c.), expressly states that the coral *lang-kan* when struck develops resonant properties.

¹ *Shi ki*, Ch. 117, p. 2 b; and *Ts'ien Han shu*, Ch. 57 A, p. 2 b. Yen Shi-ku defines the pronunciation of the two characters as *mei* and *hui* (or *hwei*), but admits for the latter also the sound *kwei* (玫音枚。瑰音回。又音瓌).

² 火齊珠。今南方之出火珠也。 This clause is interesting, inasmuch as it proves the importation of lenses into China in the first half of the seventh century,—a fact which, as will be seen, is confirmed by the T'ang Annals.

of the Emperor Yüan (48–33 B.C.),¹ with reference to jars made from this stone and three others. It is simply defined as “fine jade” in the commentary. This explanation, again, would banish any idea of burning-lenses.²

What the *mei-hui* mentioned by Se-ma Siang-ju was, no Chinese commentators really knew. Their explanations are makeshifts to conceal their lack of proper knowledge of the subject. This much seems certain, that the *mei-hui* of Sze-ch'uan was not mica (*hwo-ts'i*), first, because mica is not known to occur there; and, second, because the name *mei-hui* denotes also the rose,³ and accordingly the mineralogical term seems to refer to a rose-colored stone. For this reason it seems out of the question also that it could have been used as a lens, and there is indeed no account to this effect, mentioning the employment of *mei-hui*. The case, therefore, is one of purely literary extension of significance. The original meaning of the word having fallen into oblivion, it

¹ Regarding this work see the important study of CHAVANNES, *Documents chinois découverts par Aurel Stein*, pp. 1–10. The passage referred to is in *Pien tse lei pien*, Ch. 70, p. 13 b.

² The apocryphal work *Shu i ki*, of the sixth century, which has not come down to us in its original form, is credited with the statement, “Snake-pearls are those vomited by a snake. There is a saying in the districts of the Southern Sea (Kuang-tung, etc.) that a thousand snake-pearls are not the equivalent of a single *mei-hui*, which means that snake-pearls are low in price. Also *mei-hui* is the designation of a pearl (or bead, jewel).”

³ *Rosa rugosa*, with red and pink flowers (G. A. STUART, *Chinese Materia Medica*, p. 381; and M. J. SCHLEIDEN, *Die Rose, Geschichte und Symbolik*, p. 228, who enumerates several species of rose in China). The Japanese naturalist Ono Ranzan states that the precious stone *mei-hui* is named for the color of the flowers of *Rosa rugosa*, and invokes the Chinese work *T'ien kung k'ai wu* 天工開物 by Sung Ying-sing of 1628 (2d ed., 1637), as his authority (GEERTS, *Produits de la nature japonaise et chinoise*, Vol. II, p. 360). I cannot trace this reference in the latter work, but find there that *mei-hui* is treated as a special kind of precious stone “resembling yellow or green peas; the biggest are red, green, blue, yellow, in short, occurring in all colors; and there are also *mei-hui* like pearls” (see *T'u shu tsi ch'êng*, chapter on precious stones, *pao shi*). Yet I am convinced that Ono Ranzan encountered this statement in some Chinese book, and may have erred only in quoting the *T'ien kung k'ai wu*.

became free to assume the same meaning as *huo-ts'i*, in the rôle of an elegant term of the *estilo culto*. The fact that it really interchanges with the latter is manifested by the account of Persia in *Nan shi*,¹ where *mei-hui* are listed among the products of that country: while, as mentioned on p. 195, the analogous reports in *Pei shi*, *Wei shu* and *Sui shu* have the term *huo-ts'i* in the same passage. Thus the greatest probability is that also *mei-hui*, as used in this text of the *Nan shi*, denotes the mica of India. As regards other foreign countries, we find *mei-hui* mentioned in the *Wei lio*, written by Yü Huan between 239 and 265, as a product of the Roman Orient (Ta Ts'in),² and worn on the high head-dress of the women of the King of the Ephtalites (Ye-ta).³

After having overthrown the nebular hypotheses of foreign and Chinese scholars, the path is finally cleared for discussing the real thing, the history of burning-lenses in China. There is only one term in the Chinese language which may lay claim to having this significance, and that is *huo chu* 火珠 (the "fire-pearl").

INTRODUCTION OF BURNING-LENSES INTO CHINA. — The first historical mention of "fire-pearls" (*huo chu*) is made in the Annals of the T'ang Dynasty (618—906),⁴ where they are connected with a tribe of Malayan or Negrito stock, styled "Lo-ch'a" 羅刹, and inhabiting an island in the Archipelago east of P'o-li 婆利 (Bali). "Their country," it is said, "produces fire-pearls in great number, the biggest reaching the size of a fowl's egg. They are round and white, and emit light at a distance of several feet. When held

¹ Ch. 79, p. 8.

² HIRTH, *China and the Roman Orient*, p. 73.

³ *Lo-yang kia lan ki* 洛陽伽藍記, written in 547 by Yang Hsün-chi 楊衒之 (quoted in *T'u shu tsi ch'êng*, *Pien i tien* 67, Ye-ta, *hui k'ao* 2).

⁴ *T'ang shu*, Ch. 222 c, p. 1 b.

against the rays of the sun, mugwort¹ and rushes² will be ignited at once by fire springing from the pearl.”³ The same text, with slightly varying phraseology, is given also in the *Old History of the T'ang Dynasty*,⁴ where, however, the interesting addition occurs, that this pearl is in appearance like crystal (狀如水晶). Hence we may justly conclude that these fire-pears were convex crystal lenses, whose optical properties were utilized in producing fire for the medical purpose of cauterization.⁵

¹ Chinese *艾*, *Artemisia vulgaris*, a plant common in China and from ancient times used in cauterizing the skin (see BRETSCHNEIDER, *Bot. Sin.*, pt. 2, No. 429; pt. 3, No. 72),—a process known to us by the Japanese name *moxa* (properly *mogusa*, the Jap. word for *Artemisia*). The best leaves are taken and ground up with water in a stone mortar, the coarsest particles being eliminated, and the remainder being dried. A small portion is rolled into a pellet the size of a pea, placed upon the ulcer or spot to be cauterized. The preferred method of igniting the moxa is still by means of a burning glass or mirror (compare G. A. STUART, *Chinese Materia Medica*, p. 53). The most interesting and detailed account of this practice was written by ENGLBERT KAEMPFER in the seventeenth century (*History of Japan*, Glasgow edition, Vol. III, pp. 277—292). Kaempfer states that the Japanese used burning splinters or incense-sticks to ignite the moxa.

² KAEMPFER (*l.c.*, p. 276) informs us that the most common caustic used by the Brahmans of India is the pith of rushes, which grow in morassy places. This pith they dip into sesamum-seed oil, and burn the skin with it after the common manner.

³ 多火珠。大者如雞卵。圓白照數尺。日中以艾藉珠輒火出。

⁴ *Kiu T'ang shu*, Ch. 197, p. 1 b.

⁵ GROENEVELDT (*Notes on the Malay Archipelago*, p. 206, in *Miscell. papers relating to Indo-China*, Vol. 1), who was the first to indicate the relevant passage of the *T'ang shu* (but neglected the corresponding text of the *Kiu T'ang shu*), was therefore wrong in affirming that the fire-pearl is “evidently a kind of burning-glass, but whether of glass or crystal, and manufactured in what place, we have no means to ascertain.” We have, as will be seen farther on, the means of ascertaining that these crystal lenses were manufactured in India. Another error of Groeneveldt was to assign the fire-pears to the country of P'ò-li instead of Lo-ch'á. PELLIOU (*Bull. de l'École française*, Vol. IV, p. 283, note 3) has clearly pointed out the confusion prevailing in this chapter of the *T'ang Annals*, and has shown that it was the wild men of Lo-ch'á visiting the coasts of Champa in order to sell these crystal lenses, carrying on their trade at night, while hiding their faces during the day (*ibid.*, p. 281, but he too speaks of “lentilles de verre”). G. SCHLEGEL (*T'oung Pao*, Vol. IX, 1898, p. 178; and 1901, p. 334), who revealed the same text from the Chinese Gazetteer of Kuang-tung Province, offered the inadequate translation, “Their country produces car-

The crystal lenses, accordingly, were employed in the same manner as the burning-mirrors of copper or bronze in a former period. The *Ku kin chu* 古今注¹ of Ts'uei Pao 崔豹 of the fourth century states that the latter served for the purpose of setting mugwort on fire.²

The Annals of the Tang Dynasty indicate also the fact that in 630 King Fan-t'ou-li 范頭黎 sent an embassy to China to present such lenses.³ It is this text of the Tang Annals which gave to Li Shi-chên occasion for his general statement of the subject, as quoted above. We now observe that he has cited the text inaccurately, and has credited it with the term *huo-ts'i-chu* instead of *huo chu*. The former, however, as we have seen, denotes mica, which cannot be used for lenses; the latter relates to rock-crystal; and it is essential to discriminate between the two. Likewise it is not to the point when he asserts that the lenses now found in Champa are styled "great fire-pearls of the morning dawn." "Morning dawn" (*chao hia*) is well known to us as the designation of a specific textile fabric;⁴ and in the passage of the Tang Annals indicated it happens that the two terms "morning-dawn cloth" and "fire-pearl" (*chao hia pu huo chu* 朝霞布火珠) are closely joined, hence arose, apparently, the misunderstanding of Li Shi-chên.

buncles (*huo chu*) which are like crystals." Carbuncles certainly are not like crystals, nor can they be utilized as optical lenses. C. PUINI (*Enciclopedia sinico-giapponese*, p. 65, Firenze, 1877) had already indicated that *huo chu* is a species of quartz.

¹ Ch. c, p. 5 b (ed. of *Han Wei T's'ung shu*).

² 陽燧以銅爲之。形如鏡。何日則火生以艾承之則得火也。

³ The last clause in the definition of these is worded in the *Old History* thus: "When held against the sun at noon in order to ignite mugwort, the latter is consumed by fire" (正午向日以艾蒸之即火燃).

⁴ PELLLOT, *T'oung Pao*, 1912, p. 480; GILES, *Adversaria Sinica*, p. 394; LAUFER, *T'oung Pao*, 1913, pp. 339, 340; *Ling-wai tai ta*, Ch. 6, p. 13.

A book entitled *Sui T'ang kia hua* 隋唐佳話¹ informs us that in the beginning of the period Chêng-kuan (627—650) the country Champa (Liu-yi) offered to the Court burning-lenses (*huo chu*), in appearance like rock-crystal, stating that the people of Champa had obtained them from the Lo-ch'a country, whose inhabitants have red hair, a black skin, teeth like animals, and claws like hawks.²

The Lo-ch'a or Rākshasa, who, judging from the unflattering description of the Chinese, were a wretched, savage tribe (but sufficiently advanced to practise navigation and to trade with Champa),

¹ Quoted in *Pien tse lei pien*, Ch. 21, p. 5 b.

² Chinese *Lo-ch'a* is the transcription of the Sanskrit word *Rākshasa*. The latter is the designation for a class of man-devouring ogres with red neck and eyes, and protruding tusks, roaming about at night and doing mischief to mankind. It was believed by Groeneveldt and Schlegel that the country of the Lo-ch'a mentioned in the T'ang Annals is identical with the Nicobar Islands; but PELLIOU (*Bull. de l'École française*, Vol. iv, p. 281) has rightly demonstrated the baselessness of this theory, with the result that the country of the Lo-ch'a in question was situated east of P'o-li, which is identical with Bali, the island east of Java. GERINI (*Researches on Ptolemy's Geography of Eastern Asia*, p. 497) likewise has antagonized that theory, arguing that Lo-ch'a refers to the more southern parts of the Malay Peninsula, and perhaps stands also for the wilder tribes of Negrito-Sakai stock populating its eastern coast; but this opinion conflicts with the Chinese accounts of Lo-ch'a. In the belief of the Indians, the main abode of the Rākshasa demons was Ceylon (Langkā), which for this reason was styled also Rākshasālaya ("Abode of the Rākshasa"); and as such, Ceylon appears in the great epic poem Rāmāyaṇa, in which King Rāma combats these fierce devils of Ceylon. A country of the Rākshasa plays a signal rôle in the Tibetan cycle of legends clustering around Padmasambhava, who lived in the eighth century (see E. SCHLAGINTWEIF, *Lebensbeschreibung von P.*, I, p. 21; and LAUFER, *Roman einer tibetischen Königin*, p. 224). It would be tempting to regard the Lo-ch'a as a tribe like the Vedda of Ceylon, but for geographical reasons it is assuredly impossible to place the Lo-ch'a on Ceylon. Such a nickname as Rākshasa could certainly have been applied by the superior castes of India to any inferior aboriginal tribes (compare the note of YULE, in his *Marco Polo*, Vol. II, p. 312, regarding a Brahman tradition that the Rākshasas had their residence on the Andamans, and the analogous application in India of the words *Nāga* and *Piçāca*). Indian traditions referring to Rākshasa tribes, therefore, cannot assist us toward the identification of the Lo-ch'a country of the T'ang period, which, as justly upheld by Pelliot, was an island in an easterly direction from Bali. It may be supposed that it was the highly cultivated peoples of Java and Bali who conferred the name "Rākshasa" on that primitive tribe in their proximity.

certainly were themselves not able to produce fire-making lenses.¹ From what quarters was their supply derived? We are informed by the Annals of the T'ang Dynasty that in the year 641 Magadha in India sent to the Chinese Court tribute-gifts among which appeared fire-lenses (*huo chu*),² and, further, that Kashmir produces fire-lenses, saffron, and horses of the dragon breed.³ The latter notice is contained also in the memoirs written by the celebrated pilgrim Hūan Tsang in 646;⁴ and his statement, based on actual observation, was doubtless the source from which the official history of the T'ang dynasty drew. The Arabic mineralogists also — as, for instance, al-Akfānī — knew Kashmir as a country producing rock-crystal.⁵

In the beginning of the period K'ai-yüan (713—742) Kashmir sent as tribute "pearls of supreme purity" (*shang ts'ing chu* 上清珠), illuminating an entire house with their splendor.⁶ Possibly also in this case crystal lenses are understood.

I Tsing, the Buddhist monk and traveller, who journeyed in India from 671 to 695, observes, "It is only in China where stones are internally taken as medicine. Since rock-crystal and marble emit

¹ GERINI (*l. c.*, p. 491), who erroneously locates the Lo-ch'a on the east coast of the southern portion of the Malay Peninsula, conjectures with reference to these crystal lenses that rock-crystal "very likely" occurs in that region. This point of view is quite immaterial. Whether rock-crystal is found there or not, the Lo-ch'a certainly did not quarry it; and if they did, it was not wrought by them into lenses. Quartz, for instance, is common on the Andamans, but the natives make it only into chips or flakes used in shaving or tattooing, while even the art of eliciting fire from the stone by means of striking is wholly unknown to them (E. H. MANN, *Journ. Anthropol. Inst.*, Vol. XII, 1883, p. 381).

² *T'ang shu*, Ch. 221 A, p. 11.

³ *T'ang shu*, Ch. 221 B, p. 6. Compare CHAVANNES, *Documents sur les Tou-koue occidentaux*, p. 166.

⁴ JULIEN, *Mémoires sur les contrées occidentales*, Vol. I, p. 167, who translates "glass lenses"; and WATTERS, *On Yuan Chwang's Travels in India*, Vol. II, p. 261.

⁵ WIEDEMANN, *Zur Mineralogie im Islam*, p. 206. Al-Akfānī died in 1348.

⁶ *Tu yang tsa pien* by Su Ngo, Ch. A, p. 3 (ed. of *Pai hai*).

sparks of fire, the organs of the body, if those stones are administered, may be scorched and ripped open. Many of our contemporaries, being unaware of this fact, have suffered death in consequence of this wrong treatment.”¹ In Chinese alchemy preparations made from jade and mica played a signal part, and were consumed by ambitious devotees to insure long life or immortality.² When crystal lenses made their appearance in China, the belief was naturally fostered that fire was a substance inherent in the stone. Fire was considered as an element belonging to the male, creative, and life-giving principle called *yang*, so that a mineral partaking of it was apt to strengthen the body and to prolong life. The evil effect of the internal application of rock-crystal, as conceived by I Tsing, thus becomes intelligible: in the same manner as a crystal lens can set fire to an object, so it may cause the human body to catch fire.

The information given in the T'ang Annals with regard to the Lo-ch'a originated from the mission which carried Ch'ang Tsiün 常駿 in the year 607 into the country Ch'i-t'u 赤土. On his journey he is said to have reached the country of the Lo-ch'a, while in another passage it is stated that owing to this mission the inhabitants of the Lo-ch'a country entered into relations with China.³

¹ *Nan hai ki kwei nei fa chuan*, Ch. 3, p. 20 (ed. of Tokyo); compare J. TAKAKUSU (*Record of the Buddhist Religion*, p. 135), who wrongly takes the term *pai shi* 白石 (literally, “white stone”) for adular, which does not occur and is unknown in China; *pai shi* repeatedly appears in the votive inscriptions on Buddhist marble sculptures of the T'ang period, and is still the current expression for “marble.” It would be possible that I Tsing employed the term *pai shi* as a rendering of Sanskrit *śilopala* (“white stone”), which is a synonyme of *sphaṭika* and accordingly a variety of quartz or rock-crystal (R. GARBE, *Die indischen Mineralien*, p. 87). Takakusu speaks of “the swallowing of a stone;” the stones were of course triturated and powdered, the mass was kneaded and prepared with other ingredients.

² Under the Sui (589—618) was still extant a treatise on the Method of Prescriptions in administering Jade (*Tu yü fang fa* 服玉方法). See *Sui shu*, Ch. 34, p. 21.

³ PELLLOT, *Bull. de l'École française*, Vol. IV, p. 281.

The latter statement seems to be the more probable of the two. The date 607 may thus be fixed as the time when the Chinese made their first acquaintance with burning-lenses; and during the first part of the seventh century a somewhat lively trade in the article was carried on from Champa to China. Hence Yen Shi-ku (579—645), as mentioned, justly points to the importation of burning-lenses from the south during his time. While, as a last resort, the Lo-ch'a lenses are traceable to India, we have as yet no means of ascertaining through what channels these lenses were transmitted from India to the Lo-ch'a. At this point there is a lacune in our knowledge which I am unable to fill; it may be supposed only that Sumatra or Java, or both countries, acted as middlemen in this traffic, but I regret having no certain facts along this line to offer.

It is curious that a tribe of such a low degree of culture as the Lo-ch'a possessed burning-lenses, and was instrumental in conveying this Indian article to Champa and China. This fact we may explain from ethnographical conditions of the present time, with which we are familiar: the Lo-ch'a, though acquainted with natural fire and its uses, must have been a tribe that did not know of any practical method of producing fire. Such a people, for example, we meet among the Andamanese, of whom E. H. MAN¹ says, "The Andamanese are unable to produce fire, and there is no tradition pointing to the belief that their ancestors were their superiors in this respect. As they live in the vicinity of two islands, one of which contains an extinct, and the other an active volcano, it seems not unreasonable to assume that their knowledge of fire was first derived from this source. Being strangers to any method of producing a flame, they naturally display much care and skill in the

¹ *Journ. Anthropol. Inst.*, Vol. XI, 1882, p. 272; compare also Vol. XII, 1883, p. 150.

measures they adopt for avoiding such inconvenience as might be caused by the extinction of their fires. Both when encamped and while journeying, the means employed are at once simple and effective. When they all leave an encampment with the intention of returning in a few days, besides taking with them one or more smouldering logs, wrapped in leaves if the weather be wet, they place a large burning log or faggot in some sheltered spot, where, owing to the character and condition of the wood invariably selected on these occasions, it smoulders for several days, and can be easily rekindled when required." Nothing introduced by the English so impressed this people with the extent of their power and resources as matches. It is notable also that the household fire is not held sacred by the Andamanese, or regarded as symbolical of family ties, and that no rites are connected with it; there are not even beliefs with reference to its extinction or pollution. The Lo-ch'a must have lived under exactly the same conditions when burning-lenses were first introduced among them from India. Not familiar with any practical method of fire-making or any fire-ceremonial, they readily took to this easy expedient, as the modern Andamanese did to our matches. It is still the primitive tribes spending most of their time in the open air, like the Lepcha and Tibetans (see below), who evince a predilection for the application of the burning-lens in fire-making.

Besides the name *huo chu* 火珠, the term *huo sui chu* ("fire-igniting lens") is found in the *Chéng lei pén ts'ao*, completed by T'ang Shên-wei in 1108.¹ From the same work it follows also

¹ 火燧珠向日取得火 (*Chéng lei pén ts'ao*, Ch. 3, fol. 44, edition of 1523). This is the concluding sentence of a brief notice on *p'o-lí* (see above, p. 200). Both the *Chéng lei* and the *Pén ts'ao kang mu* accept this term in the sense of "rock-crystal" (*sphatika*), Li Shi-chên giving as synonyme the term *shui yü* 水玉, which appears in the *Shan hai king* and in the poem on the Shang-lin Palace 上林賦

that burning-lenses were manufactured in China under the Sung. Whether this was the case under the T'ang I am unable to say.

BURNING-LENSES IN INDIA AND SIAM. — The preceding Chinese accounts are clear enough to allow the inference that the so-called "fire-pearls" were lenses of rock-crystal cut into convex shape, that they were used for cauterization in the same manner as reported by Pliny, and that they were introduced into China, through the medium of the Lo-ch'a and of Champa, from Kashmir, or other regions belonging to the culture-zone of India. In short, what the

of Se-ma Siang-ju: its transparency, he says, equals that of water, its hardness that of jade, hence this term; the name "water-jade" is identical with rock-crystal (其瑩如水。其堅如玉。故名。水玉與水精同名). The opinion of both T'ang Shên-wei and Li Shi-chên goes back to Ch'ên Ts'ang-k'î of the T'ang period, whose definition of *p'o-li* is as follows: "*P'o-li* is a precious stone of the Western countries. It belongs to the category of hard stones, and is developed in the soil. According to the opinion of some it results from the transformation of ice that is a thousand years old; but this is certainly not the case" (陳藏器曰。玻瓈西國之寶也。玉石之類。生土中。或云千歲冰所化。亦未必然). Nobody, as far as I know, has as yet explained the statement of Li Shi-chên that the original mode of writing is 頗黎, and that this name *P'o-li* is the designation of a country. *T'ai p'ing yü lan* (Ch. 808, p. 6) quotes a work *T'ien chu ki* 天竺記 ("Memoirs of India") as follows: "In the Himalaya, there is the mountain of precious stones producing the complete series of the seven gems (*saptaratna*), all of which may be obtained. Only the *p'o-li* gem is produced on such lofty peaks that it is difficult to obtain" (大雪山中有寶山諸七寶並生取可得。唯頗黎寶生高峯難得). Here we are confronted with the reproduction of an Indian notion that meets its parallel in the *Ratnaparīkshā*, according to which rock-crystal is a product of Nepal (L. FINOT, *Lapidaires indiens*, p. 56). Certainly the people of India did not hunt for glass on the heights of the Himalaya. The King of Nepal adorned himself with pearls, *p'o-li*, mother-of-pearl, coral, and amber (*T'ang shu*, Ch. 221 A, p. 1); his *p'o-li* certainly were a kind of rock-crystal, as also S. LÉVI (*Le Népal*, Vol. 1, p. 164) understands, but not glass. The Buddhist monk Hwei Yüan 慧苑 of the T'ang period, in his Glossary to the Buddhāvataṃsaka-sūtra (華嚴經音義, Ch. 1, p. 8, ed. of *Shou shan ko ts'ung shu*, Vol. 94; see Bunyiu Nanjio, No. 1606), explains *p'o-li* as "to some degree resembling in appearance rock-crystal (水精; that is, the variety of rock-crystal indigenous in China), yet occurring also in red and white varieties."

Chinese received were Indian manufactures. Hence it is legitimate to conclude that the Chinese name *huo-chu*, conferred upon these lenses, represents the translation of a corresponding Sanskrit term. Such, indeed, exists in the Sanskrit compound *agnimanî*, the first element of which (*agni*) means "fire," answering to Chinese *huo*; and the second part of which (*manî*) signifies a "pearl, bead, gem, or jewel," exactly like the Chinese word *chu*.¹ Moreover, Sanskrit *agnimanî*, according to the Sanskrit Dictionary of Boehtlingk, is an epithet of the stone *sūryakānta*, which means "beloved by the sun," so called because it produces fire under the influence of solar rays. Other synonymes are *tapanamanî* ("sun jewel"), *tāpana* ("dedicated to the sun"), *ḍiptopala* ("refulgent stone"), *agnigarbha* ("essence of fire"), — all of these, as correctly seen by L. FINOT,² referring to rock-crystal. A Hindu treatise on precious stones, the *Navaratnaparikshā*, says, under the subject of rock-crystal, that the

¹ Although apparently formed in imitation of this Sanskrit expression, the term *huo chu*, notwithstanding, pre-existed in China independently of Indian influence, but in a widely different sense. The following story is on record in the Annals of the Tsin Dynasty (*Tsin shu*, Ch. 99, p. 1; biography of Hêng Hūan 桓玄). His mother, née Ma 馬氏, was sitting out one night with her companions in the moonlight, and saw a shooting-star fall into a copper basin filled with water. In the water appeared what looked like a fire-pearl (*huo chu* 火珠) of two inches, diffusing a bright, clear light. Madame Ma took it out with a gourd ladle and swallowed it. When she gave birth to her son, the house was filled with effulgent light; hence the infant received the name Ling-pao 靈寶 (that is, "Supernatural Treasure"). It is evident that this "fire-pearl" was a product of meteoric origin. A similar account is found in the Bamboo Annals: Siu-ki 修己, the mother of the Emperor Yü 禹, saw a falling-star, and in a dream her thoughts were moved till she became pregnant, after which she swallowed a spirit pearl (LEGGE, *Chinese Classics*, Vol. III, Prolegomena, p. 117). The term *huo chu* appears again in *Tsin shu* (Ch. 25, p. 13 b) in connection with the description of the costume, ornaments, and paraphernalia worn by the heir-apparent. There is no explanation of its meaning in this text: perhaps it was a flaming or sparkling gem. In the latter sense I encountered the term in two passages of the *Shi i ki* (Ch. 5, p. 5 b; and Ch. 7, p. 2; ed. of *Han Wei ts'ung shu*); in one case the question is of an extraneous hairpin adorned with a fire-pearl dragon and a phoenix.

² *Lapidaires indiens*, p. XLVII.

variety of the stone which, struck by sunlight, instantaneously elicits fire, is styled *sūryakānti* by the connoisseurs. The physician Narahari from Kashmir, who wrote a small *lapidarium* in the beginning of the fifteenth century, observes in regard to the same stone, "If it is smooth, pure, without fissures and flaws in the interior, if polished so that it displays the clearness of the sky, and if from contact with solar rays fire springs from it, it is praised as genuine."¹ Narahari dilates likewise on the medical virtues of the stone, to which he lends the attribute "sacred," and which, if honored, procures the favor of the sun.

Fire-production by means of lenses was not a very ancient, or a common, or a popular, practice in India, any more than in classical antiquity.² In the oldest epoch of India's history, the Vedic period, we hear only of fire-making by means of friction from wooden sticks. The daily birth of Agni, the god of fire, from the two fire-sticks (*araṇī*), is often alluded to in Vedic literature.

¹ R. GARBE, *Die indischen Mineralien*, p. 89. Garbe commits the error of regarding this stone as the sunstone, being misguided by the Sanskrit name *sūryakānta*, and speculates that also the Indian name has come with this stone to Europe. All this is erroneous. First, the sunstone is not known to occur in India, but it occurs near Verchne Udinsk in Siberia, Tvedestrand and Hitterö in Norway, Statesville in North Carolina, and Delaware County in Pennsylvania (BAUER, *Edelsteinkunde*, 2d ed., pp. 528, 529); second, the name "sunstone" is bestowed upon this kind of feldspar by us, not by the Indians, because it reflects a spangled yellow light originating from minute crystals of iron oxide, hematite, or gothite, included in the stone, and which both reflect the light and give it a reddish color (FARRINGTON, *Gems and Gem Materials*, p. 179); this case, therefore, is totally different from that which induced the Hindu to name a certain variety of rock-crystal "sun-beloved;" third, feldspars, like the sunstone, are not made into burning-lenses, such as are described by Narahari. After arriving at his fantastic result, Garbe is forced to admit that Narahari is wrong to classify the (that is, Garbe's) "sunstone" among the quartzes; but the physician of Kashmir who does not speak of "our" sunstone is perfectly right in grouping rock-crystal among quartzes, and the blunder is solely on the part of Garbe.

² The utility of the burning-lens, of course, has its limitations. It is dependent upon a cloudless sky and the power of strong sunlight. At night when fire may be most needed it is put out of commission.

They are his parents, the upper being the male, and the lower the female; or they are his mothers, for he is said to have two mothers.¹ The *Vāyu Purāna*, one of the oldest of the eighteen Purānas, presumably dating in the first half of the fourth century,² mentions three kinds of fire, — the solar fire (*saura*), or the pure one, or the fire of the gods; fire proceeding from lightning, procured from trees ignited by a lightning-stroke; and fire obtained by friction. Whether and how the first-named was secured we do not know. It would be very tempting to believe that this celestial fire, obtained by concentrating the rays of the sun, was the result of an application of lenses, as, indeed, is still the case in Siam (see below). Such a conclusion, however, would hardly be justified. In all probability, only the divine or transcendental fire, like that in the Greek myth of Prometheus, is here intended. Also in the Avesta, the sacred writings of the ancient Iranians, in which five kinds of fire are distinguished, the fire of heaven burning in the presence of Ahura Mazda is known;³ and there is no record of the use of burning-lenses on the part of the Iranians.⁴

¹ Compare A. A. MACDONELL, *Vedic Mythology*, p. 91; H. OLDENBERG, *Religion des Veda*, p. 105; R. ROTH, *Indisches Feuerzeug* (*Z. D. M. G.*, Vol. 43, pp. 590—595); F. SPIEGEL, *Arische Periode*, p. 147. The modern processes of fire-making in India are well described by E. THURSTON, *Ethnographic Notes in Southern India*, pp. 464—470 (Madras, 1906).

² V. A. SMITH, *Early History of India*, p. 305 (3d ed., Oxford, 1914).

³ A. V. W. JACKSON, in *Grundriss der iranischen Philologie*, Vol. II, p. 641; W. GEIGER, *Ostiranische Kultur*, p. 253.

⁴ A material difference between the fire-worship of the ancient Indians and Iranians lies in the point that fire-making ceremonies predominate with the former (a good and succinct description of these will be found in the new book of L. D. BARNETT, *Antiquities of India*, pp. 156—161), while the latter were eager to seek for the sites of natural fire (JACKSON, *Zoroaster*, pp. 98—101); so that the artificial production of fire was not part of their rites. Much valuable information relative to the Persian worship of fire has been gathered by DIEULAFOY (*Suse*, pp. 393 *et seq.*). The Avesta (*Vidēvdāt*, xiv, 7; F. WOLFF, *Avesta*, p. 405) mentions fire-implements without description of particulars, and we seem to have no information as to Iranian methods of fire-making. This is the more deplorable, as the Persian form of fire-worship spread into all parts of the world, — to

In Sanskrit medical literature I have not yet found any reference to burning-lenses,¹ but the employment of burning-mirrors in medical practice is well ascertained for ancient India. Such mirrors, probably made of metal,² are twice mentioned in the medical work *Ashtāṅga-Hṛidaya*.³ In one case, certain drugs are to be ground on it; and a counterpart of this practice appears in a recipe of the famous Bower Manuscript, coming down from the middle of the fifth century: "Let long pepper and turmeric be rubbed repeatedly on a mirror, and anoint with them the eye when it suffers severe pain; it will then quickly become well." In the other case (mentioned in the above work), the wound of a person bitten by a rat is to be cured by an arrow or a mirror, and, as

Rome (F. CUMONT, *Mysteries of Mithra*, p. 99; and *Oriental Religions in Roman Paganism*, p. 137), to India (R. G. BHANDARKAR, *Vaishnavism*, pp. 151—155), and to China (Mastri, in B. de MEYNARD, *Prairies d'or*, Vol. I, p. 303; J. J. MODI, *References to China in the Ancient Books of the Parsees*, in his *Asiatic Papers*, pp. 241—254; CHAVANNES, *Le Nestorianisme*, *Journal asiatique*, 1897, pp. 60, 61, 74, 75; PELLIOU, *Bull. de l'École française*, Vol. III, pp. 669, 670). It could very well be conceived that the Persian Magi, who appear in India under the name Maga and in China as Mu-hu (*Mémoires concernant les Chinois*, Vol. XVI, p. 230; CHAVANNES and PELLIOU, *Traité Manichéen*, p. 170), should have had a certain share in the diffusion of burning-lenses; but this, for the time being, remains purely a matter of speculation, as we are entirely ignorant of any evidence in the case. One curious coincidence, however, deserves attention in this connection, and this is the sacred caudle of the Siamese lighted with "celestial fire" by means of a burning-glass (mentioned below) and the same "celestial fire" kept constantly burning in a lamp by the Persian kings as a symbol of the perpetuity of their power; and it passed with the mystical ideas of which it was the expression to the Diadochi, and from them to Rome, where the celestial fire received as its emblem the inextinguishable fire that burned in the palace of the Cæsars, and which was carried before them in official ceremonies.

¹ Cauterization was practised by Indian physicians (see HOERNLE's translation of *Saṅgṛaha Sāṁhitā*, pp. 74—80).

² Regarding mirrors in ancient India, see the writer's *Dokumente der indischen Kunst*, I, p. 174.

³ That is, the "Quintessence of the Eight Parts of Medicine," ascribed to the physician Vāghbata, probably written before the eighth century (J. JOLLY, *Indische Medicin*, p. 8; the time of the work is fully discussed by JOLLY in *Z. D. M. G.*, Vol. 54, 1900, pp. 260—274).

supposed by Dr. Hoernle, by the reflection of the sun-rays focussed on it.¹

The lack of information on objects of reality so painfully obtrusive in Indian literature, combined with the defect of a sound chronological sense, renders it impossible to trace a *terminus a quo* for the utilization of burning-lenses; and the records of the Chinese present our only reliable source in this respect. Indeed, the students of India have never taken up this problem, and may now hear for the first time that burning-lenses were ever known in India. The information coming from Chinese sources, which establish the date of the first introduction of such lenses into China in the beginning of the seventh century, allows the inference that they were made and employed in India prior to this date. This result, however trifling it may appear at first sight, is significant in bearing out the fact that long before the Arabic invasion of India (710) burning-lenses were operated there, and that the idea cannot have been imported into India by the Arabs.

Sacred fire was annually obtained from crystal lenses at the Court of the Emperor Akbar, and all the fires of the imperial household were lighted from it. His historian, Abul Fazl Allami (1551—1602), thus describes the ceremony:² “At noon of the day, when the sun enters the nineteenth degree of Aries, the whole world being then surrounded by its light, they expose to the rays of the sun a round piece of a white and shining stone, called in Hindi *sūrajkrānt*. A piece of cotton is then held near it, which catches fire from the heat of the stone. This celestial fire is committed to the care of proper persons. The lamp-lighters, torch-bearers, and cooks of the household use it for their office; and when the year has passed in happiness, they renew the fire. The vessel

¹ Compare A. F. R. HOERNLE, *The Bower Manuscript*, p. 160.

² H. BLOCHMANN, *Ain I Akbari*, Vol. I, p. 48 (Calcutta, 1873).

in which this fire is preserved is called 'fire-pot.' There is also a shining white stone, called *chandrkrānt*, which, upon being exposed to the beams of the moon, drips water." ¹

Burning-lenses are still employed in Siam at state ceremonies, like the New Year festival, or during the tonsure-ceremonial when Buddhist monks are ordained, for obtaining what is called the "celestial fire" (*fai fa*). The medium enlisted is a huge wax candle, styled *thien chai* (literally, "victorious taper"), which is prepared under the direction of the head priest of some royal temple. The wax employed for a single taper amounts to twenty-six pounds in weight; the wick consists of a hundred and eight cotton threads, a number sacred with the Buddhists; and the length is about five feet. Round it are inscribed the magical formulas and diagrams which are prescribed by custom. This sacred candle is usually lighted by means of celestial fire, generated from the sun by the use of a huge burning-glass (*wen fai*) mounted on a richly gilded and enamelled frame. The fire thus kindled is protected in a lamp until the auspicious moment arrives for applying it to the "torch of victory." The lamp is then brought before the king, who takes

¹ The Hindi word corresponds to Sanskrit *candrakānta* ("beloved by the moon"), in the same manner as does *sūryakānta* to the above Hindi name for the crystal lens. *Candrakānta* is a kind of rock-crystal, generally believed in India to shed water when the moon shines on it (FINOT, *Lapidaire indiens*, p. XLVII). The Tibetan rendering of this term is *c'u šel* ("water crystal"), explained as "a fabulous magic stone supposed to have the power of producing water or even rain" (JÄSCHKE, *Tibetan-English Dictionary*, p. 562). GRECARD's opinion (*Mission scientifique dans la Haute Asie*, Vol. II, p. 407), that this stone "employed by the Tibetan sorcerers who have the power of causing or stopping rain" probably is jade, is inadmissible; the Tibetan word for "jade" is *yang-ti* or *g-yang-ti* (*Polyglot Dictionary of K'ien-lung*, Ch. 22, p. 64), the history of which I hope to trace some day in another place. — Tibetan has also a term for a burning-lens, — *me šel* ("fire crystal") or *sreg byed šel* ("burning crystal"); likewise Lepcha *mi šer* or *šer mi* (MAINWARING-GRÜNWEDEL, *Dictionary of the Lepcha Language*, pp. 285, 434). According to H. VON SCHLAGINTWEIT (*Reisen in Indien und Hochasien*, Vol. II, pp. 201, 202) burning-glasses imported from China are widely used in Tibet for fire-making; he himself witnessed in Sikkim the employment of such glasses directed on tinder.

a taper, termed the "ignition candle," which he lights at the celestial fire, while reciting a prayer-formula. The king then hands the ignition candle to the head priest, who applies its flame to the *thien chai*. During this performance the attendant chapter of monks rehearses a prayer. The torch is kept lighted in a special white gauze frame. A solemn ceremony takes place also at the time when it is extinguished.¹

ICE-LENSES. — Everybody knows that also a flake of ice, if cut into the form of a convex lens, may serve as a burning-glass with good effect. The Chinese have had this experience; and one of their books, the *Po wu chi* 博物志, a collection of notes on remarkable objects and occurrences, has it on record that "fire may be obtained by cutting a piece of ice into circular shape, holding it in the direction of the sun, and placing mugwort (*Artemisia*) behind the ice, so that it falls within the shadow."² It should be added that this notice figures under the title "juggler's art" 戲術; and it is from this class of performers, who swallow fire and swords, that the demonstration of such an experiment might be expected. Nevertheless, Li Shi-chên found it advisable to insert this notice in his essay on the mugwort,³ as if it had ever been a common practice of physicians to apply the moxa to their patients by means of an ice-lens. This, however, remains open to doubt. Mugwort is said to have received the name "ice-terrace" (*ping-t'ai*) from the employment of ice-lenses. The authorship of the work above quoted is attributed to Chang Hua 張華, who lived from 232 to 300. If Chang Hua of the third century should really have written this

¹ After G. E. GERINI, *The Tonsure Ceremony as performed in Siam*, p. 161 (Bangkok, 1893). — Regarding crystal lenses in Japan see GEERTS, *Produits de la nature japonaise et chinoise*, p. 243.

² 削冰令圓舉以向日以艾於後承其影則得火 (Ch. 4, p. 4b; edition printed in Wu-ch'ang).

³ *Pên ts'ao kang mu*, Ch. 15, p. 3.

passage, the case would indeed be notable in establishing the fact that four centuries prior to the first introduction of burning-lenses from Indian regions the latter were known in China as an apparently native idea. Indeed, this text has been accepted in this sense, and was marched forward by G. SCHLEGEL¹ as a strong bulwark in his argumentation for the indigenous origin of burning-lenses in China; but this plea will melt away as easily as the bit of ice when its function as lens was over. Also Schlegel had access to WYLIE'S *Notes on Chinese Literature*, from which we learn (p. 192) that the work *Po wu chi*, originally drawn up by Chang Hua, was lost in the Sung period (960—1278); that the present book with that title was probably compiled at a later period on the basis of extracts contained in other publications; and that there are many quotations from it in the ancient literature which do not appear in the modern edition. There is, accordingly, no guaranty whatever that any text in this work, as it is now extant, goes back to the third century and originates from the hand of Chang Hua. The text in question is quoted by Li Shi-chên from the *Pi ya* 埤雅, a dictionary compiled by Lu Tien 陸佃 (1042—1102), so that from this indication we may carry it to the latter part of the eleventh century. It is certainly far older than that; but it cannot have been penned by Chang Hua, and, at the very best, cannot date back farther than the first half of the seventh century, when burning-lenses first became known in China. The *Annals of the T'ang Dynasty*, as we noticed, record burning-lenses in the possession of the Lo-ch'a as an entirely novel affair, describing their use and effect, and this incontrovertibly proves that they were unknown in times previous. Neither do the T'ang

¹ *Uranographie chinoise*, p. 142; *Nederlandsch-Chineesch Woordenboek*, Vol. I, p. 674; and *T'oung Pao*, Vol. IX, 1898, p. 179. The allegation of Schlegel that lenses of ice were used before the invention of glass is pure invention, being contained neither in this nor in any other Chinese text.

authors assert that they were known at an earlier date (Yen Shiku, on the contrary, insists on their being imported "at present;" that is, in his own lifetime), nor is there any record in the historical annals relating to the third century to the effect that such lenses should have been in vogue at that period. Whoever reads with critical eyes the account now sailing under the false flag of the *Po wu chi* will soon notice that in its style it is worded on the basis of the text of the Tang Annals, and also that it materially depends upon the latter, — materially, because it was only after, and in consequence of, the introduction of foreign crystal lenses, that the experiment with ice could have been conducted in China. This idea was not conceived by the Chinese as the result of a natural observation or optical study, which they never cultivated; but ice was resorted to as a makeshift, as a substitute for the costly rock-crystal, on the theory of their nature philosophy, that the latter is transformed ice; crystal and ice, being products of a like origin, were thought to be able to bring about the same effect.

CONCLUSIONS. — When we now attempt to reconstruct the general history of burning-lenses, the principal fact standing out is that China, despite the opposite contention of some enthusiasts, has not the shadow of a claim to their invention, but, on the contrary, admits her debt to Lo-ch'a and Champa; that means, to India. China received them from India in the same manner as mediæval Europe and the Arabs received them from Greece and Rome. The problem, therefore, crystallizes around the central point: In what reciprocal relation or obligation are India and Hellas? Hellas, at the outset, is entitled to the privilege of chronological priority, and

can point to the well-fixed date 423 B.C., when Aristophanes wrote his *Clouds*. At that time, we may assert positively, burning-lenses were unknown in India, for which we have merely a retrospective *terminus a quo* lying backward of the seventh century A.D. Negative evidence in this particular case is somewhat conclusive: for, with all their ideas of the sacredness of fire and its prominent position in religious worship, the ancient Hindu themselves would not have allowed such an excellent contrivance to escape, — a contrivance that would have brought the realization of their dreams of celestial fire. The fact remains that none of the Sanskrit rituals ever mention such an implement, which, for this reason, cannot have been of any significance in the culture-life of the nation. It is therefore highly improbable, nay, impossible, that the Hindu should have independently conceived the invention. Even if our conclusion, based on Chinese documents, that burning-lenses were employed in India prior to the seventh century, should be substantiated in the future by the efforts of Indian research, and, for example, be carried back to a few centuries earlier, this would hardly change our result fundamentally, or overthrow the impression that the use of such lenses belongs to the mediæval epoch of Indian history. There are good reasons for upholding this opinion and for connecting their introduction with the influence upon India of Hellenistic-Roman civilization. First, we may say negatively that it was not Assyria which transmitted the idea to India. In that case, we should justly expect that it would turn up there at a much earlier date, and occur simultaneously in ancient Persia; but Zoroastrian Persia, like Vedic India, lacks them entirely. This observation justifies us in concluding also that burning-lenses played a

very insignificant part, if any, in Mesopotamia; if they did, we should find them also in Greece at a much earlier date. Without pressing the question of the when and where of the original invention, we must be content at present to regard the Greeks as the people who, we know positively, made the first use of optical lenses. The second negative evidence that is impressed upon us is this, that Alexander's campaign cannot be made responsible for the transmission. It is needless to insist that the historians of Alexander are silent about it; coeval India is likewise so; and it is inconceivable that an idea, though Alexander's genius should have carried it into the borders of India, would have borne fruit on her soil only as late as the middle ages. The Arabs, as already observed, did not transfer it, either, to India. If we strictly adhere to our chronological result, we are clearly carried into the Gupta period, which, taken in a wide sense, extends from about 300 to 650 A.D., and which, particularly in the fourth and fifth centuries, was a time of exceptional intellectual activity in many fields,¹ in mathematics, astronomy, and medicine, all of which have received an appreciable stamp of Western influence.² Indeed, as emphasized by Smith, the eminent achievements of this period are mainly due to contact with foreign civilizations, both on the East and on the West, and the fact of India's intercourse with the Roman Empire is indisputable. The conquest of Mālwa and Surāshtra by Caudragupta II Vikramāditya toward the close of the fourth century opened up ways of communication between Upper India and Western lands which

¹ V. A. SMITH, *Early History of India*, 3d ed., p. 304.

² See particularly A. WEBER, *Die Griechen in Indien* (*Sitzungsberichte Berliner Akademie*, 1890, pp. 921—925); G. D'ALVIELLA, *Ce que l'Inde doit à la Grèce*, pp. 95—119 (Paris, 1897); G. THIBAUT, *Indische Astronomie*, pp. 43, 76.

gave facilities for the reception of European ideas. It is accordingly a reasonable conclusion that burning-lenses were transmitted to India, not from Hellas, but from the Hellenistic Orient of the Roman Empire, in a period ranging between the fourth and sixth centuries, to be passed on to China in the beginning of the seventh century. The introduction of the burning-mirrors alluded to in the Bower Manuscript, in my opinion, falls within the same epoch, emanating from the same direction.

ADDITIONAL NOTES. — P. 202, note 2. The tree in question is the *pārijāta* (see *Fan yi ming i tsi*, Ch. 25, p. 27 b, ed. of Nanking).

P. 206, note. Compare also *lang-tang* 琅璫 and 銀鐺; an interesting notice on this word is contained in the *Néng kai chai man lu*, Ch. 7, p. 27 b (*Shou shan ko ts'ung shu*, Vol. 71).

The interesting study of Dr. M. W. de Visser (*Fire and Ignis Fatui in China and Japan*, reprint from *M.S.O.S.*, 1914, pp. 97—193) reached me only a short while ago when my manuscript was in the press. Dr. de Visser touches some questions dealt with on the preceding pages, though from a different point of view, but he accepts Schlegel's statements and the text of the *Po wu chi* without criticism.