

SAPPHIRES FROM CHANGLE IN SHANDONG PROVINCE, CHINA

By Jingfeng Guo, Fuquan Wang, and Gerry Yakoumelos

Sapphires were recently found in alluvial deposits and in situ in basaltic rocks near Wutu, Changle County, in central Shandong Province. The fact that significant amounts of sapphire have been found in situ at Changle makes it unique among sapphire deposits in basaltic terrains around the world. (Sapphires have been found in situ elsewhere, but never in such abundance in basalt.) Changle sapphires occur in a range of colors (dark blue, blue, greenish blue, and yellow), but they are predominantly dark blue. Fe, Ga, Ti, Co, and V are the most abundant trace elements present. The gemological properties of Changle sapphires are consistent with those from similar alkalic basalt environments.

The sapphire potential of the People's Republic of China (PRC) was recognized several years ago, following the discovery of alluvial deposits of this gem material in several provinces. Previous reports in English on Chinese sapphires include the survey of the PRC's gem resources by Keller and Wang (1986), the description of the Mingxi deposit in Fujian Province

by Keller and Keller (1986), and the report on the Wenchang deposit in Hainan Province (formerly Hainan Island) by Wang (1988). In all three articles, the authors speculated that the sapphires obtained from these alluvial deposits were derived from surrounding Cenozoic basalts; however, no locality-specific studies were available to corroborate this hypothesis.

More recently, in the late 1980s, local farmers discovered alluvial sapphires near the township of Wutu, Changle County (henceforth, Changle), in central Shandong Province. These sapphires are characterized by their large size, dark color, and absence of fractures (figure 1). Some show distinctive zonation (figure 2). Follow-up geologic surveys were conducted by the 7th Geological Brigade of the Shandong Bureau of Geology and Mineral Resources. Subsequently, large quantities of sapphire were discovered in Tertiary alkalic basalt lava flows, where they occur *in situ* as "megacrysts" (a general term for large crystals, without any implication with respect to origin). Although the only mining thus far has been by local workers digging in the alluvium, officials at the Shandong Bureau of Geology and Mineral Resources estimate that more than 50,000 carats of rough from the Changle deposits

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were exported to Hong Kong, Thailand, Australia, and the United States in the period 1988–1991.

To date, however, no studies have been published on the Changle deposits. The object of this report, which is based on information obtained during the authors' early-1989 visit to Changle and from discussions with senior geologists of the 7th Geological Brigade, is to briefly describe the Changle deposits and present information with respect to the geologic occurrence and origin of the sapphires.



Figure 1. Dark blue sapphires are being recovered from alluvial deposits in Changle County, Shandong Province, China. Sapphires have also been found *in situ* in the basalt. These two Changle sapphires each weigh approximately 3 ct.

LOCATION AND ACCESS

Wutu is situated about 8 km southeast of the town of Changle, which is about 150 km east of Jinan, the capital of Shandong Province (figure 3). Modern highways and a railway make Changle easily accessible year-round. Changle is an agricultural region, and foreign visitors can obtain access to the area by contacting the local Changle County government.

The sapphires are found within a roughly 5 km radius of Wutu (see figure 3). At the time of our 1989 visit, the "mining operation" was represented by sporadic holes in the ground, without any organization. Mechanized operations by joint ventures between the government and foreign companies (e.g., Shandong Leyang Pty. Ltd.) are now under way to explore the sapphire-producing potential of the area more fully.

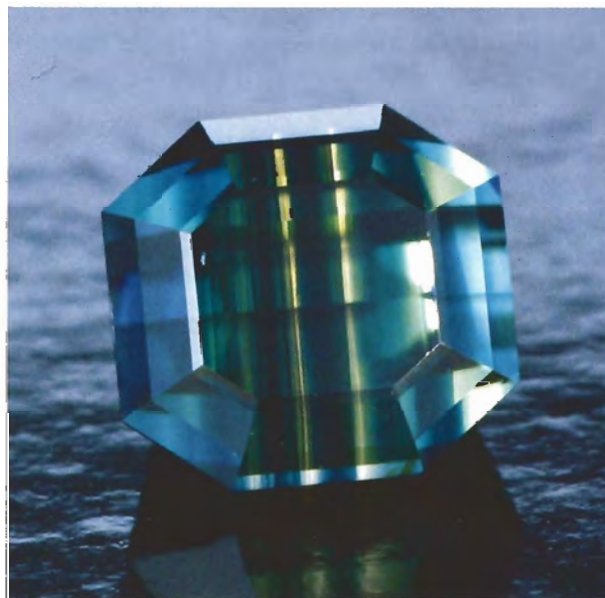
GEOLOGY AND OCCURRENCE

The first discovery of sapphire near Wutu was in alluvial sediments filling the topographically long and

narrow gully at Xinwang (figure 4). In 1988, geologists from the 7th Geological Brigade discovered sapphires *in situ* in basaltic rocks at two localities in the vicinity of Wutu: Fangshan and Qiujiache (again, see figure 3). From field observations, it appears that the basalts at Fangshan occur stratigraphically somewhere near the top of the Niushan Group or the bottom of the Yaoshan Group (see table 1). Potassium-argon geochronologic ages determined for these basalts are 16–17 My (lower Miocene; Chen et al., 1985), which places them geologically in the Niushan Group. The basalts at Qiujiache also are within the Niushan Group, but at a different stratigraphic position. However, the occurrence of sapphires at these two localities differs: At Fangshan (figures 5 and 6), the sapphires are concentrated in a layer at least 2 m thick that contains abundant ultramafic "xenoliths" (foreign inclusions in an igneous rock) within a massive basalt flow; at Qiujiache, the sapphires occur in a layer 0.3–0.6 m thick within a different basalt flow that does not have xenoliths.

At the Fangshan locality, there is a positive correlation between the abundance of xenoliths and of sapphires; that is, the greater the number of xenoliths (which may reach 30%–40% of the basalt by volume) present, the greater the number of sapphire megacrysts found within the basalt. The xenoliths have been deeply weathered, and the sapphires remain embed-

Figure 2. Distinctive zoning is seen in some Changle sapphires like that evident in this 0.70-ct stone. Photo © GIA and Tino Hammid.



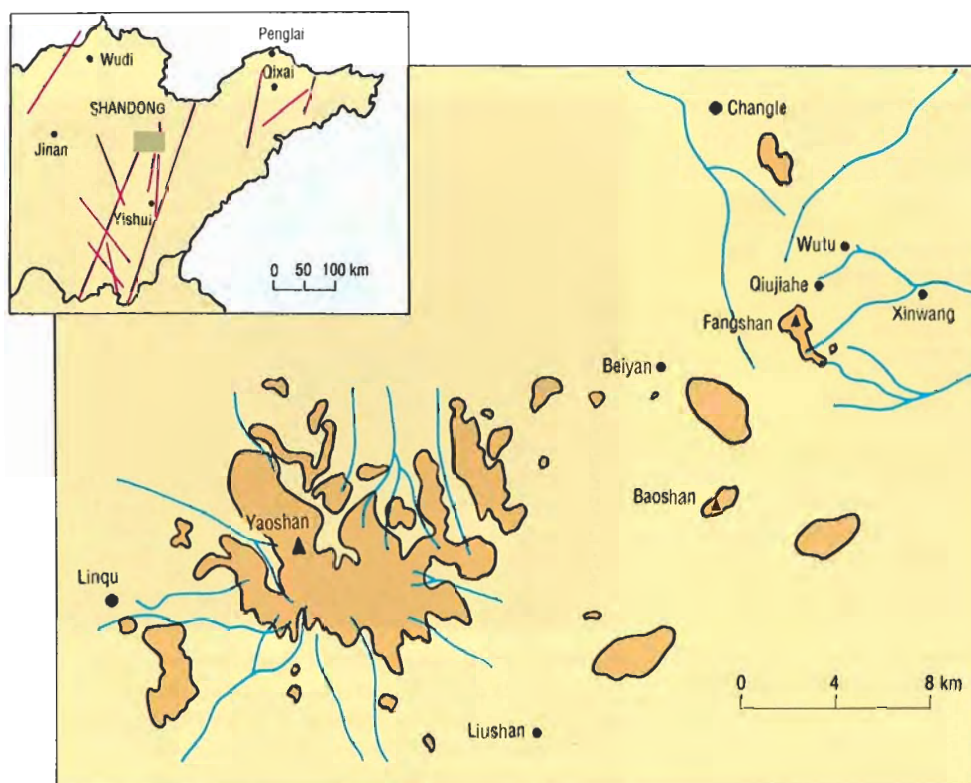


Figure 3. This map shows the location and distribution of Cenozoic basalts in the Linqu-Changle region, Shandong Province. The shaded areas represent the exposed basaltic rocks. Local hills are indicated by solid triangles; circles represent cities and towns. The major drainage patterns, through which alluvial stones might travel, are also shown. The inset at the upper left shows the location of regional faults which provide channels for volcanic eruption, across Shandong Province.

ded in the basaltic matrix (figure 7). Similar occurrences of sapphire in basalt are known from the Inverell-Glen Innes region of New South Wales and the Anakie-Rubyvale region of Queensland, Australia (MacNevin, 1972; Stephenson, 1976, 1990), as well as from other localities, but the abundance of sapphires in the Changle deposits is much greater than it is in these other localities.

The basalts in Shandong Province, which are part of the Cenozoic (less than 65 My) Basalt Belt of northeastern China, are extensive. Most basalts in this area are Miocene in age and range from 9 to 21.5 My; only minor amounts were extruded during the Pliocene age. In general, the basalts are alkalic in composition (i.e., high in sodium and potassium). The ultramafic xenoliths characteristic of the Fangshan sapphire deposits are derived from the Earth's mantle (i.e., below the crust and above the core). They are found throughout the volcanic sequence in varying amounts. Sapphires, however, occur only in specific situations and are particularly abundant in basalts with an age of 16–17 My, as at Fangshan. Two major regional fault trends, extending northeast and northwest, respectively, may have played an important role in controlling volcanic activity in the region (again, see figure 3).

MINING

The horizon that contains the alluvial sapphires lies about 4 to 5 m below the surface. To date, most of the sapphires recovered have been picked by hand from the

Figure 4. The sapphire-bearing gravels are found in a largely agricultural area at Xinwang, near Wutu in Changle County. Only a portion of the long, narrow gully is visible from this angle.



TABLE 1. The stratigraphic relationship of units in the Linqu-Changle-Yishui volcanic province.^a

Time scale	Stratigraphic unit	Description ^b	Sapphires
Pliocene	Yaoshan Group	Basalt lavas (15 m) Interbedded clay-coal layer Conglomerate (30 m)	Yes
Upper Miocene	Shanwang Group	Basalt lavas (10 m) Thin coal layer Basalt lavas Sandy conglomerate (54 m) Clay, shales	No
Lower Miocene	Niushan Group	Partially exposed basaltic lavas interbedded with pyroclastics (total >143 m)	Yes
Archean	Taishan Formation	Highly deformed amphibolites and feldspathic gneisses	No

^a Information from the 7th Geological Brigade, Zhu et al. (1985), and Wang and Jin (1986).

^b The thickness of each layer is given where available.

alluvium (again, see figure 4), although the joint ventures mentioned earlier are to bring in heavy equipment, presumably for an open-pit operation. Only relatively large crystals are recovered by hand picking, but the daily yield can be significant, as well as quite variable. There was no processing plant at the time of our visit, but we understand that such plants will be part of the mechanized operations planned.

Figure 5. Sapphires have been found in situ in basalt in this hill at Fangshan. The arrow points to the in situ digging site near the top of the hill.



Figure 6. At the digging site at Fangshan (see figure 5), sapphires are concentrated in a xenolith-rich band of unknown thickness (2 m is visible) within the basalt. This was the only in situ operation at the time of the authors' 1989 visit, and was exploited solely for mineral specimens of sapphire in basalt. Mr. Shao Zhixin, a local resident, is shown looking for such specimens.

At the time of our visit, there was no organized mining of the *in situ* deposits, although we know that a few people have extracted sapphire-basalt specimens (again, see figures 6 and 7). A detailed exploration program is presently being carried out by the 7th Geological Brigade to assess the economic potential of the sapphire deposits in the entire region. The joint ventures were formed in 1991 to bring organized exploration, mining, processing, treatment, cutting, and distribution to the Changle deposits. As yet, no details are available of the results of these ventures. Such operations are under the authority of the Bureau of Mineral Resources of the Changle County government, which can be contacted for further information.

THE CHANGLE SAPPHIRES

Sapphires recovered from this area range from blue to greenish blue to yellow, and they are sometimes strongly zoned (again, see figure 2). Most of the blue sapphires are dark (again, see figure 1), like those from the Anakie Field, in Queensland, Australia. In diaphaneity, they range from transparent to translucent (silky). The rough sapphires are relatively large, 5–20 mm on average, with exceptional crystals up to

10 cm along the c-axis. Blue sapphires smaller than 5 mm can be cut in their natural state. However, those larger than 10 mm are usually too dark and may require heat treatment before being marketed. None of the material we have encountered would produce asterism.

We examined a random sample of more than a hundred individual sapphire grains, some of which were extracted directly from the basalts. The crystals are typically barrel shaped, pseudo-hexagonal, and terminated at both ends (again, see figure 7). Many of the grains are broken fragments, but most of these show one or two original crystal faces. Those sapphires that have their natural surfaces preserved show extensive etch features, the result of interaction with the basalt magma in which they were carried to the surface. Typically, they do not exhibit distinct dichroism. Specific gravity was determined by the hydrostatic method to range from about 3.98 to 4.09.

Further studies on these sapphire samples were carried out at Macquarie University, Sydney, Australia. The minor and trace elements were determined using energy-dispersive particle-induced X-ray emission (PIXE) analysis. Fe, Ga, Ti, Co, and V were found to be among the most abundant elements present (table 2). Ti contents of the yellow sapphires were lower than those of the blue varieties, resulting in higher Fe/Ti ratios for the yellow sapphires. We noted that the deeper the blue color of the sapphires was, the lower the Fe/Ti ratios were.

Results of quantitative chemical analysis by electron microprobe revealed the following mineral inclu-



Figure 7. A dark blue sapphire megacryst is seen here embedded in its basalt matrix, as recovered from Fangshan in Changle County. The yellow fragments adjacent to the sapphire are weathered ultramafic xenoliths.

sions: uranium-and-thorium-rich zircon, titanium-rich columbite, sodium feldspar, apatite, ilmenite, and magnesium-iron spinel. This combination is similar to that found in sapphires from other basaltic areas such as Hainan Island, China, and the Inverell-Glen Innes, Anakie-Rubyvale, and Lava Plains regions in eastern Australia. The zircon inclusions are orange-red in color and can be as large as 1 mm; the columbite

TABLE 2. Minor- and trace-element contents in dark blue, blue, and yellow Changle sapphires.^a

Element (ppm)	Sample (color) ^b							
	SD12 (d.blue)	SD14 (d.blue)	SD19 (d.blue)	SD13 (blue)	SD17 (blue)	SD18 (blue)	SD15 (yellow)	SD17 (yellow)
Fe	7188	7868	7245	7642	9046	9593	7629	8800
Ga	207	190	194	222	275	211	249	250
Ti	330	276	125	173	161	190	65	79
Co	31	35	33	34	35	35	28	30
V	28	15	17	19	21	13	19	21
Cr	9	29	11	5	<3	<3	<3	46
Mn	5	7	6	7	5	11	7	5
Cu	<3	<3	4	<3	4	4	<3	<3
Zn	<3	<3	<3	<3	<3	<3	<3	<3
Fe/Ti	22	29	58	44	56	50	117	111

^a Sapphire samples were analyzed using the proton microprobe at the CSIRO Division of Exploration Geoscience, North Ryde, NSW, Australia, with the assistance of Dr. W. L. Griffin.

^b d.blue = dark blue. Note that sample SD17 is a particolored crystal; separate analyses were done on blue and yellow sections of this crystal.

inclusions are typically black, with metallic luster, and also range from several hundred microns to 1 mm. Columbite was found to be one of the most common mineral inclusions in sapphires from basaltic terrains. U-Pb dating of the zircon inclusions gave the same age (16 My) as the host Fangshan basalt (16.3–16.4 My). The implications of these data are beyond the scope of this report and are the topic of a separate paper (Guo, in preparation).

CONCLUSION

The occurrence of sapphires *in situ* in basalts at Changle confirms the relationship between gem-quality sapphires and basalts, which has been recognized but not always proved at other, similar sapphire deposits throughout the world, such as Thailand, Australia, and elsewhere in China. Sapphires found in basaltic terrains were clearly brought to the surface by the rapidly ascending alkalic basaltic magmas along with other heavy materials (e.g., mantle xenoliths). However, the genesis of the sapphires at depth remains a mystery, because the data at hand are inadequate to determine whether the sapphire crystals formed directly from the basalt magma (i.e., they are phenocrysts) or crystallized elsewhere and were merely transported to the surface as xenocrysts (i.e., crystals that are for-

eign to the rock in which they occur). One way of approaching this problem is to study the mineral and fluid inclusions within the sapphires. This type of study is currently in progress (e.g., Guo et al., 1992; Guo, in preparation). Preliminary indications are that sapphires have no direct genetic linkage with their host basalts; that is, they are not phenocrysts of basaltic magmas, but rather they are the product of complex magma-mixing processes.

Although gemstone resources in China have been neglected for years, these newly discovered sapphire deposits have attracted the attention of the international gem community. Preliminary exploration in the vicinity of the Wutu district alone has revealed that the sapphire reserve is large, on the order of tons (7th Geological Brigade, pers. comm., 1992). At present, the recovery of sapphires from this area is negligible in comparison to the estimated reserve.

However, it is possible within the near future that cooperation already established between Chinese government agencies and foreign gem companies will make sufficient foreign capital available to bring this deposit into full-scale production using modern mining methods. Considering the vast area in eastern China that is covered by similar alkalic basalt rocks, the long-term prognosis for economic sapphire deposits is good.

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