

## **Relations between chemical composition of granitic rocks and metallization in the Outer Zone of southwest Japan**

NOBORU ŌBA

Institute of Earth Sciences, Faculty of Science  
Kagoshima University, Kagoshima, Japan 890

AND

MICHITOSHI MIYAHISA

Geological Institute, Faculty of Science  
Ehime University, Matsuyama, Japan 790

**Abstract:** In the outer zone of southwest Japan, Tertiary granitic rocks of the Southwestern Outer Zone-type are genetically related to the associated metallic ore deposits represented by the Obira-type, which are characterized by a wide range of complex metallization, such as, pneumatolytic, hypothermal and xenothermal types, with most of the ores having extremely variable mineral assemblages.

The physical conditions of formation suggested by mineral assemblage, type of metallization and mode of occurrence, show that the ore deposits formed at high temperatures and shallow depths, and harmonize with those of the Southwestern Outer Zone-type granitic rocks. Throughout that region, granitic rocks of high silica-content are commonly accompanied by many ore deposits; but, in contrast, those of low silica-content by little or no ore deposits. Plots on AKF diagram representing granitic rocks accompanied by many ore deposits suggest concentration in alkali and aluminium during the differentiation and contamination-assimilation of magmas.

### **INTRODUCTION**

Figure 1 shows the distribution of granitic bodies belonging to the Southwestern Outer Zone-type (Shibata, 1962) and the associated metallogenetic provinces. From detailed studies on these granitic rocks and their associated metallic ore deposits, which are distributed mainly within the Shimanto major belt south of the Butsuzo-Itogawa tectonic line in the outer zone of southwest Japan, data dealing with their mode of occurrence, petrography, petrochemistry, mineral assemblage, metallization, petrographic and metallogenetic provinces, and relationships to the tectogenetic belts have been obtained (Miyahisa, 1955, 1958, 1961, 1969; Ōba, 1962a, b, c, d, 1966, 1967). This paper is a summary of a paper presented by the authors at the 5th Meeting of the IUGS-IGCP Circum-Pacific Plutonism Project held in Kuala Lumpur, Malaysia, in 1975.

### **SOUTHWESTERN OUTER ZONE-TYPE GRANITIC ROCKS**

In the outer zone of southwest Japan three types of granitic rocks are recognised; simple plutonic, volcano-plutonic complex, and synkinematic, the last two being equivalent to transitional (to volcanic rock) and dynamo-metamorphosed types which were used in a paper by Ōba (1962a). The Southwestern Outer Zone-type granitic rocks comprise rocks of both simple plutonic and volcano-plutonic complex types, but exclude the synkinematic rock-type.

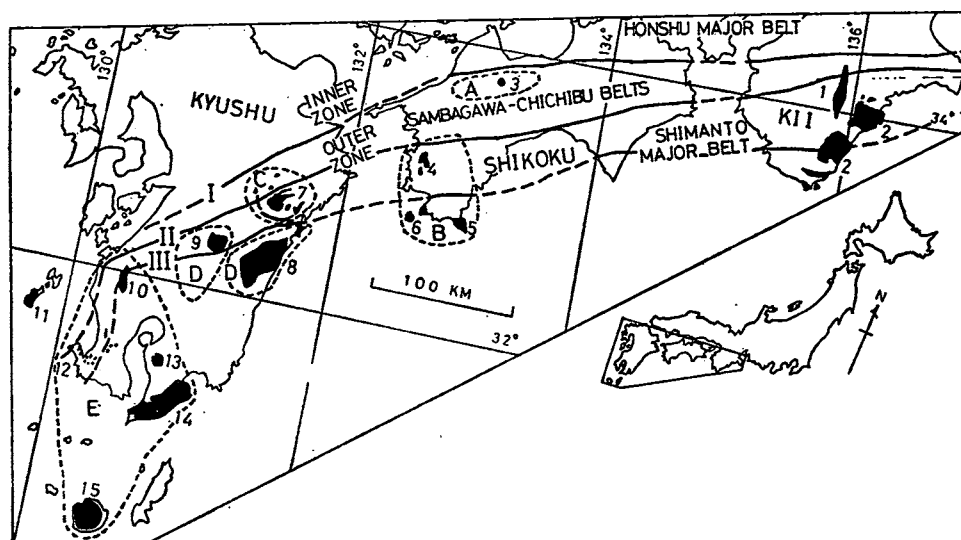


Fig. 1. Distribution of rock bodies of the Southwestern Outer Zone-type granitic rocks and the associated metallogenetic provinces in the outer zone of southwest Japan. Tectonic lines: I, Median tectonic line; II, Butsuzo-Itogawa tectonic line; III, Nobeoka-Shibisan tectonic line. Bodies of granitic rock: 1, Dogawa; 2, Kumano; 3, Omogo; 4, Takatsukiyama; 5, Ashizurimisaki; 6, Okinoshima; 7, Okueyama; 8, Osuzuyama; 9, Ichifusayama; 10, Shibisan; 11, Shimokoshikijima; 12, Satsuma Peninsula; 13, Takakumayama; 14, Osumi; 15, Yakushima. Metallogenetic provinces: A, Ishizuchi; B, South Shikoku; C, Obira; D, Matsuo; E, Suzuyama.

As seen from Table 1, the ages of the granitic rocks, derived mainly from K-Ar determinations on biotite, range from about 12 to 22 m.y. (Miller, Shibata and Kawachi, 1962; Kawano and Ueda, 1966; Shibata and Nozawa, 1967; Shibata, 1968), i.e. lower to upper Miocene age. The granitic bodies form discordant cupolas, lenticular dikes, dome-like stocks and batholiths. Field evidence shows that at least part of the consolidation of these granitic rocks took place at shallow depths (Oba, 1967), and petrochemical characteristics indicate that these granitic rocks belong to one genetic system, involving high temperatures, low water-vapor pressures and shallow depths (Oba, 1962a, d).

#### METALLIC ORE DEPOSITS ASSOCIATED WITH THE SOUTHWESTERN OUTER-ZONE-TYPE GRANITIC ROCKS

The Southwestern Outer-Zone-type granitic rocks are accompanied by many metallic ore deposits, such as, tin, lead, zinc, tungsten, antimony, arsenic, iron sulphide and others (Table 1). Field evidence shows that igneous activity and contemporaneous mineralization took place during two stages, early to middle Miocene and late Miocene (Miyahisa, 1961).

Miyahisa (1955, 1961) proposed the term "Obira-type ore deposits" for those ore deposits characterized by the following features: (1) extremely variable and complex mineral assemblages; and (2) a mineralization sequence from skarn-mineralization with Pb-Zn-Fe, boron metasomatism and tourmalinization, Sn-W mineralization, to complex sulphide metallization of Fe, Sn, Bi, Pb, Zn, Cu, As and Ag. Mi-

TABLE 1  
 MODES OF OCCURRENCE, ROCK TYPES AND CHRONOLOGICAL AGES OF THE SOUTHWESTERN OUTER ZONE-TYPE  
 GRANITIC ROCKS; AND ASSOCIATED METALLIZATION AND METALLOGENETIC PROVINCES

Regions	Rock bodies	Modes of occurrence	Rock types	K-Ar ages (m.y.)	Associated metallization	Metallogenic provinces
Obira		Cupolas, downward enlargement	BG; aplite and tourmaline-greisen in marginal facies		Sn, Pb, Zn, Cu, Fe, Sb, As, Ag, Bi	
	Okueyama	Complex of batholith with roof-pendants and ring dikes	HBGD, GP; tourmaline-greisen in marginal facies	21 ± 2	"	Obira
Kyushu	Ichifusayama	Stock	HBGD, BG	11, 14 ± 1	Sb, Ag, Au, As	
	Osuzuyama, Tomiyama	Cupolas and stocks with deroofting	Complex of BG, GP, QP, GR, R	15 ± 2	As, Au, Sb, Fe, Pb, Zn	Matsuo
	Shibisan	Lenticular stock	Porphyritic HBGD	13, 15 ± 4	Pb, Zn, As, Sn	
	Takumayama	Dome-like stock with roof-pendants	BG, garnet-bearing leucoplogranite	16 ± 1	W, Mo, Bi, Au, As, Pb, Zn, Sb, Ag, Sn, U	
	Suzuyama, Satsuma Peninsula, Osumi	Group of cupolas and stocks of a small scale	GD, GP, QP, GR, R	12 ± 2 (Mukayama)	Sn, Pb, Zn, Fe, Ti, Sb, As, Au, Ag	Suzuyama
Yakushima	Batholith	HBGD	14 ± 1, 21 ± 1, 22	Au, Ag, As, Mo		
Ishizuchi, Omogo		Dome-like batholith	Megaporphyritic BG	13 ± 2, 14 ± 1	W, Mo, Au, Bi, As	
		Ring dike complex	Complex of GD, BG, GP, QP; pyroxene andesite	14 ± 2 (Omogo)	Pb, Zn, Sb	Ishizuchi
Shikoku	Takatsukiyama (Uwajima)	Stock	HBGD	12 ± 2	As, Sb	South Shikoku
	Ashizurimisaki	Stock	Porphyritic BD, BG	13, 13 ± 2	Pb, Zn	
Kii Peninsula	Kumano	"Acidic igneous complex"; funnel-shaped body, cone sheet and lava-flows (Aramaki and Hada, 1965)	Complex of GP, R	14 ± 2	Cu, As, Fe, Pb, Zn, Co	

HBGD: Hornblende-biotite granodiorite, GD: Granophyrite, BD: Biotite adamellite, BG: Biotite granite, GP: Granite porphyry, QP: Quartz porphyry, GR: Granophyre, R: Rhyolite

TABLE 2  
SILICA-CONTENTS OF THE SOUTHWESTERN OUTER ZONE-TYPE  
GRANITIC ROCKS AND ACCOMPANYING METALLIZATION

Regions	Rock bodies	SiO <sub>2</sub> % Aver. *	B	U,Th	Sn	As	Pb,Zn	Cu	W	Main ore deposits	Metallogenetic provinces
	Obira	73.85	●	×	●	●	O	O	△	Obira, Hoei, Toroku	Obira
	Hinokage		△	×	●	O	O	△	△	Kiura, Mitate	
	Okueyama	66.81	●	×	●	×	×	×	×		
Kyushu	Osuzuyama		●	×	△	O	△	●	×	Matsuo, Tomitaka	Matsuo
	Ichifusayama	65.38	×	×	×	×	×	×	×		
	Shitbisan	67.53	●	×	△	△	△	●	×		
Shikoku	Suzuyama		●	●	O	△	△	●	●	Suzuyama, Isaku	Suzuyama
	Takakumayama	74.30	O	△	△	O	△	△	O	Tarumizu, Hanaoka, Mobira	Suzuyama
	Osumi	67.27	●	●	×	△	△	△	×	Sata	
Shikoku	Yakushima	69.56	●	●	△	△	×	×	O	Anbo, Funayuki	
	Ashizurimisaki	65.97	●	●	●	×	△	×	×		
	Uwajima	65.96	●	×	×	●				Fujinokawa	South Shikoku
Shikoku	Okinoshima	66.35	●	×	×	×	×	×	×		
	Omogo	67.33	●	×	×	×	●	×	×		Ishizuchi
Accompanying ore deposits: ● Extremely abundant    O Abundant    △ Accompanied    ● Little    × Scarce or no *Analytical data from Oba (1963, 1965)											

neral assemblage, type of metallization and mode of occurrence show that part of these ore deposits were formed at high temperatures and shallow depths. The Obira-type ore deposits in the outer zone of southwest Japan were divided by Miyahisa (1958, 1961) into several metallogenetic provinces (Figure 1).

RELATIONSHIP BETWEEN CHEMICAL COMPOSITION OF THE SOUTHWESTERN OUTER ZONE-TYPE GRANITIC ROCKS AND METALLIZATION

Generally, metallic ore deposits in the inner zone of Kyushu which forms a part of the inner zone of southwest Japan, are associated with Cretaceous granitic rocks and are characterized mainly by copper sulphide-iron sulphide and oxide. In contrast, metallic ore deposits in both the outer zones of Kyushu and Shikoku which form a large part of the outer zone of southwest Japan, are associated with Tertiary granitic rocks and are characterized mainly by tin, tungsten, arsenic, antimony, etc. (Miyahisa, 1969). The Cretaceous granitic rocks of the inner zone of Kyushu consists mainly of intermediate granodiorite and tonalite, but the Tertiary granitic rocks of the outer zones of Kyushu and Shikoku are mainly felsic to intermediate rocks such as leuco-aplogranite, granite and granodiorite.

Throughout the whole of the Southwestern Outer Zone-type granitic rock terrain, clearly rocks of high silica-content are generally accompanied by many ore deposits characterized mainly by Sn, W, As, Pb, Zn and Sb; but, in contrast, rocks of low silica-content by little or no ore deposits (Table 2, Figure 2). It can be clearly seen from Figure 3, that granitic rocks associated with many metallic ore deposits plot closer

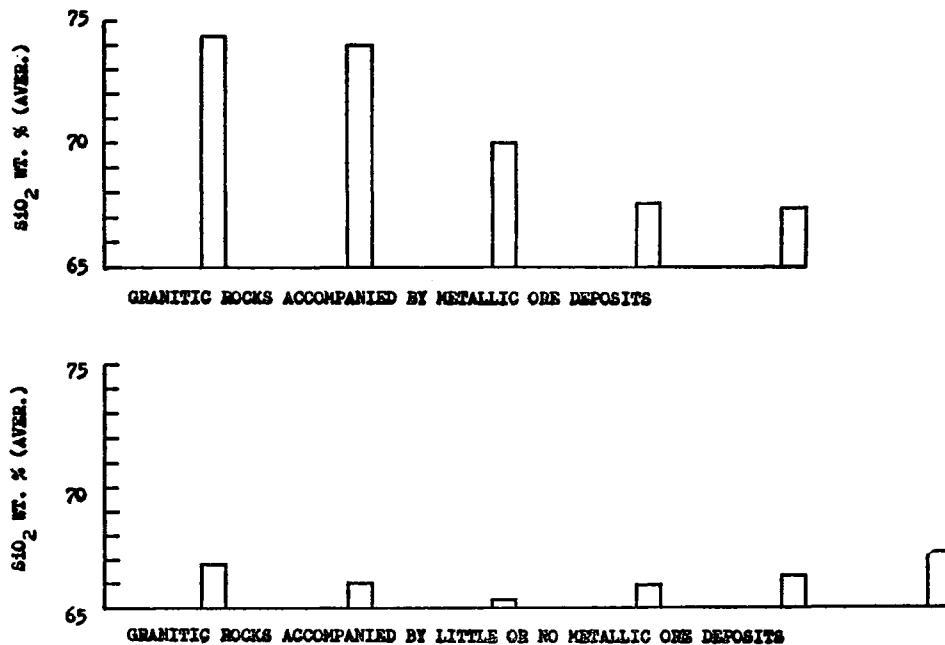


Fig. 2. Histograms showing relationship between silica-contents of the Southwestern Outer Zone-type granitic rocks and accompanying metallic ore deposits.

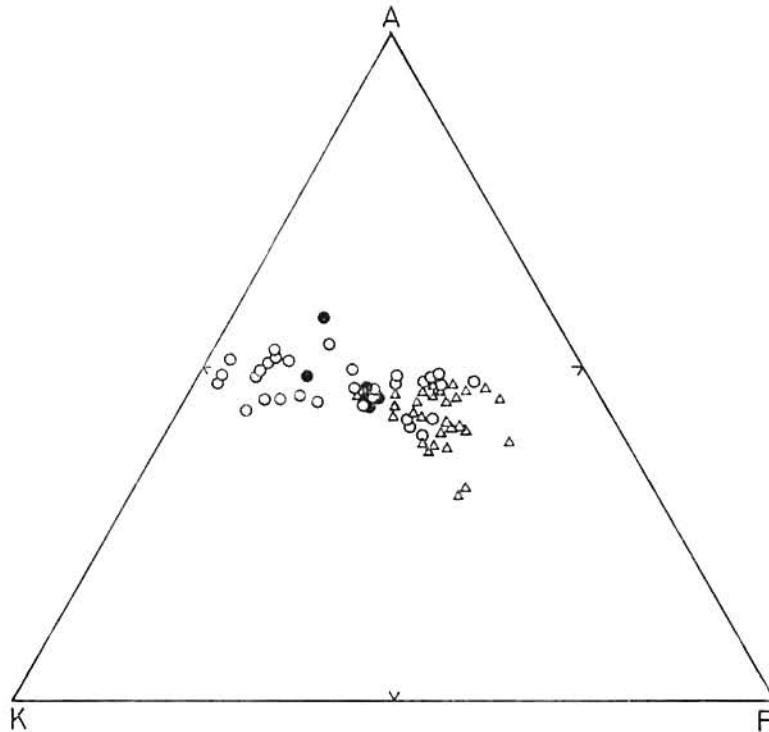


Fig. 3. AKF diagram showing relationship between chemical compositions of granitic rocks and accompanying metallic ore deposits in the outer zone of southwest Japan. Reconstructed from Miyahisa's (1969) original figures. A:  $\text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3 - (\text{CaO} + \text{Na}_2\text{O} + \text{K}_2\text{O})$ , K:  $\text{K}_2\text{O}$ , and F:  $\text{FeO} + \text{MnO} + \text{MgO}$ . Symbols ●, ○ and △ represent granitic rocks associated with extremely abundant, and little or no metallic ore deposits.

the A-K side and somewhat nearer to the A apex, than do the granitic rocks associated with little or no ore deposits. Such a trend is thought to reflect the combined effects of progression in magmatic differentiation and contamination-assimilation during upwelling of granitic magmas through sedimentary envelopes.

#### SUMMARY

In the outer zone of southwest Japan, granitic rocks have a close genetic relationship with the associated metallic ore deposits ("Obira-type") and played an important ore-bearer role. The Obira-type metallic ore deposits are characterized by wide range and complex metallization such as, pneumatolytic, hypothermal and xenothermal types. Most of these deposits can be considered to have been formed at high temperatures and shallow depths on the basis of mineral assemblage, type of metallization and mode of occurrence. They appear to be in good harmony with the physical conditions of intrusion of the Southwestern Outer Zone-type granitic rocks.

Throughout the outer zone of southwest Japan, granitic rocks with high silica-content are accompanied by many metallic ore deposits, but those of low silica-content are associated with little or no ore deposits. The compositionally plots of

granitic rocks accompanied by many ore deposits on an AKF diagram are thought to reflect concentration of alkalis and aluminium during the processes of differentiation and contamination-assimilation of magmas.

#### ACKNOWLEDGEMENTS

The authors are indebted to members of the IUGS-IGCP Circum-Pacific Plutonism Project for discussions on this work: in particular, Dr. P.C. Bateman, U.S. Geological Survey, for his encouragement; Dr. J. A. Roddick, Geological Survey of Canada, for his critical review which improved the manuscript; and staff members of the Geological Survey of Malaysia and Department of Geology, University of Malaya, for their cooperation. Thanks is also due to Dr. K. Tomita of Kagoshima University for his cooperation.

#### REFERENCES

- ARAMAKI, S., and HADA, S., 1965. Geology of the central and southern parts of the acid igneous complex (Kumano acidic rocks) in southeastern Kii Peninsula *J. Geol. Soc. Japan*, 71, 494-521, (in Japanese with English abstract)
- KAWANO, Y., and UEDA, Y., 1966. K-Ar dating on the igneous rocks in Japan (V); granitic rocks in southwestern Japan. *J. Japan. Assoc. Mineralogists, Petrologists, Econ. Geologists*, 56, 191-211, (in Japanese with English abstract).
- MILLER, J.A., SHIBATA, K., and KAWACHI, Y., 1962. Potassium-argon ages of granitic rocks from the outer zone of Kyushu, Japan. *Geol. Survey Japan Bull.*, 13, 712-714.
- MIYAHISA, M., 1955. On the Obira metallogenetic province; some problems of ore deposits associated with granitic rocks. *Earth Science*, No. 23, 15-24, (in Japanese with English abstract).
- MIYAHISA, M., 1958. Tertiary acid intrusives and related metallogenetic provinces in the outer zone of Kyushu and Shikoku, Japan. *Mem. Ehime Univ., Sci., Sec. II, 3*, No. 1 145-155. (in Japanese with English abstract).
- MIYAHISA, M., 1961. Geological studies on the ore deposits of Obira-type in Kyushu: (1) General geology and metallogenetic provinces. *Japan. J. Geol. Geogr.*, 32, 39-54.
- MIYAHISA, M., 1969. Geological Studies on the ore deposits of Obira-type in Kyushu (II): Some geochemical features of granitic rocks. *Mem. Ehime Univ., Sci., Ser. D, 6*, No. 2, 9-30. (in Japanese with English abstract).
- ŌBA, N., 1962a. Petrochemical studies of the Kyushu Outer Zone granites, Japan. *J. Geol. Soc. Japan*, 68, 162-171.
- ŌBA, N., 1962b. Geological and petrochemical studies of the Kyushu Outer Zone granites; the heterogeneity and the contamination-effect. *J. Geol. Soc. Japan*, 68, 255-268.
- ŌBA, N., 1962c. The contamination-trends in the Kyushu Outer Zone granites and some typical granitic rocks in other regions. *J. Geol. Soc. Japan*, 68, 469-480.
- ŌBA, N., 1962d. The Kyushu Outer Zone granites and the Shimanto orogeny. *Sci. Repts. Kagoshima Univ.*, No. 11, 73-85.
- ŌBA, N., 1963. Chemical composition of the Kyushu Outer Zone granitic rocks. *Sci. Repts. Kagoshima Univ.*, No. 12, 35-51.
- ŌBA, N., 1965. The heterogeneity on the Osumi granodiorite. *Sci. Repts. Kagoshima Univ.*, No. 14, 59-70.
- ŌBA, N., 1966. Geological meaning of the granitic rocks in the western district of the Shimanto terrain. *Sci. Repts. Kagoshima Univ.*, No. 15, 13-24, (in Japanese with English abstract).

- ŌBA, N., 1967: Granitic rocks in the western district of the Shimanto terrain. In Sudo, T., *Professor H. Shibata Memorial Volume* 34-40.
- SHIBATA, H., 1962. Chemical composition of Japanese granitic rocks in regard to petrographic provinces; Part 10, Petrographic provinces of Japan. *Sci. Repts. Tokyo Univ. Education, Sec. C*, 8. No. 72, 33-47.
- SHIBATA, K., 1968. K-Ar age determination on granitic and metamorphic rocks in Japan. *Geol. Survey Japan, Report 227*, 73 p.
- SHIBATA, K., and NOZAWA, T., 1967. K-Ar ages of granitic rocks from the outer zone of Southwest Japan. *Geochemical J.*, 1, 131-137.