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Petrochemistry of the Nishinoshima Islands*

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Abstract: Volcanological classification has been discussed on the Nishinoshima Islands and their associated marine area in order to clarify their geological significance in the western Pacific. From the petrochemical points of view, it is safe to get the conclusion that three groups of rocks from Nishinoshima-kyuto Island (abbr. NO), Nishinoshima-shinto Island (abbr. NN) and the associated marine area (abbr. NM) are likely to belong to the similar rock series, in other words, to high-alkali tholeiite and low-alkali tholeiite near high-alkali tholeiite on the basis of the rock classification. For the sake of comparison, petrochemical data have been cited from marine area associated with the Izushoto Islands, Ooshima Island, Miyake-jima Island, Mikurajima Island, Hachijojima Island, Aogashima Island, Myojinsho Reef, Bayonnaise Rocks, Torishima Island, Sofuiwa Rock, Yuojima Islands, Uracas Island, Moug Island, Agrihan Island, Pagan Island, Alamagan Island, Sarigan Island and Anatahan Island. The rock series from Yuojima Island, marine area associated with Izushoto Islands—Bayonnaise Rock—Nishinoshima Islands—Minami-Yuojima—northern Mariana Islands, and Islands from Ooshima to Kita-Yuojima have been mainly characterized by alkali basalt, high-alkali tholeiite and low-alkali tholeiite, respectively.

1. Introduction

The origin and development of the islands arc and trench in the western Pacific has been one of the most controversial problems in geoscience of this century. On this account, a lot of excellent papers have been published to clarify the problem under controversy (for example, PEIVE, 1980). Under these circumstances, petrochemical and geological problems are summarized by the present writer and others (AOKI, 1969; AOKI *et al.*, 1976; AOKI and TSUCHI, in press).

The Nishinoshima Islands are composed of the old island called "Nishinoshima-kyuto" and the newly formed island called "Nishinoshima-shinto" (AOKI and OSSAKA, ed., 1974). Twenty rock samples, namely ten from the marine area related to the Nishinoshima Islands, two from Nishinoshima-kyuto Island and eight from Nishinoshima-shinto Island, are chemically analized to throw light upon the mechanizm under which the islands arc, including the Nishinoshima Islands, might have been formed.

2. Sampling station and locality

As shown in Fig. 1, rock samplings were carried out at seven stations around the Nishinoshima Islands by the use of dredge. Their sample number, location and water depth of respective stations are summarized as follows:

Stn. 1-1-1	27°17.30′N	140°53.80′E	1025m
Stn. 1-2-2	27°15.00′N	140°50.75′E	675m
Stn. 1-2-5	Ditto		

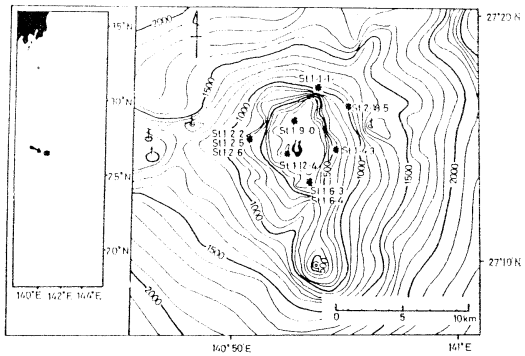

Fig. 1. Location map for the Nishinoshima Islands and the position of dredge.

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Stn. 1-2-6	Ditto		
Stn. 1-4-3	27°14.50′N	140°54.75′E	595m
Stn. 1-6-3	27°13.13′N	140°53.40′E	195m
Stn. 1-6-4	Ditto		
Stn. 1-9-0	27°15.65′N	140°52.78′E	65m
Stn. 1-12-4	27°14.39′N	140°52.39′E	65m
Stn. 2-18-5	27°16.20′N	140°55.40′E	1040m

As shown in Fig. 2, rock samplings were also carried out at eight localities on the Nishinoshima Islands for chemical investigation. Their sample number and location of respective localities are summarized as follows:

NO-02: Uppermost lava of Nishinoshima-kyuto Island

NO-05: Intrusive of Nishinoshima-kyuto Island

NN-02: Lava of the 1st crater of Nishinoshima-shinto Island

NN-05: Lava of the 2nd crater of Nishinoshima-shinto Island

NN-11: Lava of the 2nd crater of Nishinoshima-shinto Island

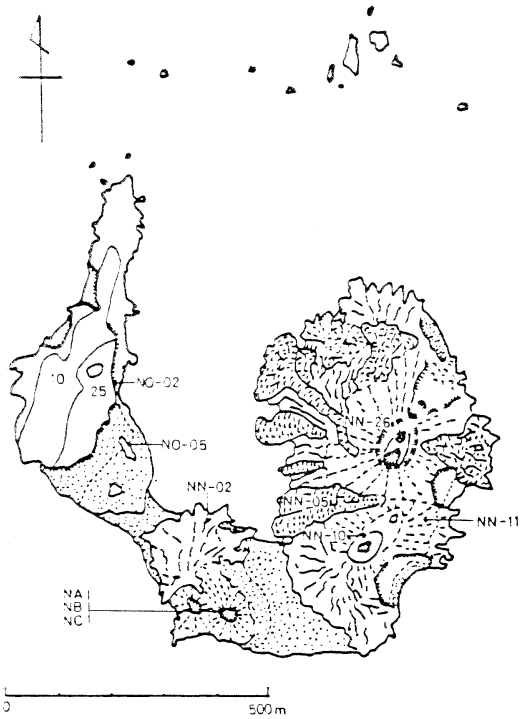

Fig. 2. Topography of the Nishinoshima Islands with contours in meters. The positions are also indicated for the locality of rock sampling for the petrochemical investigation.

NN-26: Lava of the 5th crater of nishinoshima-shinto Island

NA: NB: NC: Lava of the vent in the 1st crater of Nishinoshima-shinto Island

3. Results

Petrochemical examinations have been done on rocks from the marine area around the Nishinoshima Islands, Nishinoshima-kyuto Island and Nishinoshima-shinto Island, with special attention to alkalinity.

As clear from Table 1 and Fig. 3, chemical compositions of the marine area around the Nishinoshima Islands seem to change in wide area in SiO_2 contents and those from Nishinoshima-kyuto Island are characterized by the more limited variation in SiO_2 contents. Rocks from Nishinoshima-shinto, on the contrary, are likely to have the limited chemical composition ranging 58.35 to 59.56 wt. % of SiO_2.

As far as the alkali-SiO_2 relation is concerned, three groups of rocks from the Nishinoshima Islands appear to have the chemical composition characteristic in rock series of high-alkali tholeiite or low-alkali tholeiite near high-alkali tholeiite (AOKI and Ito, 1969).

The following data can be cited for the sake of comparison of rocks from the Nishinoshima Islands and their associated marine area with those of the Izu-Bonin-northern Mariana Islands arc and the marine area intimately related with the Izushoto Islands.

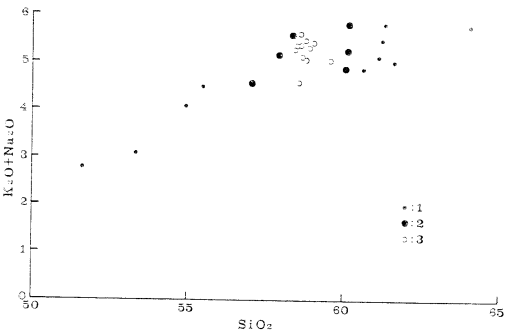

Fig. 3. Na_2O+K_2O-SiO_2 diagram for volcanic rocks in the Nishinoshima Islands and their associated marine area.

1. Rocks from the marine area around the Nishinoshima Islands.
2. Rocks from the Nishinoshima-kyuto Island.
3. Rocks from the Nishinoshima-shinto Island.

Table 1. Chemical composition of rocks from the marine area around the Nishinoshima Islands, the Nishinoshima-kyuto Island and the Nishinoshima-shinto Island. Stn. 1-1-1: Olivine-Cpx andesite, Stn. 1-2-2: Cpx andesite, Stn. 1-2-5: Porphyrite, Stn. 1-2-6: Olivine basalt, Stn. 1-4-3: Olivine-Cpx andesite, Stn. 1-6-3: Two-pyroxene andesite, Stn. 1-6-4: Ditto, Stn. 1-9-0: Ditto, Stn. 1-12-4: Ditto, Stn. 2-18-5: Cpx andesite. NO-02: Cpx andesite, NO-05: Olivine-Cpx andesite, NN-02: Two-pyroxene andesite, NN-05: Ditto, NN-10: Ditto, NN-11: Ditto, NN-26: Ditto, NA: Ditto, NB: Ditto, NC: Ditto. Analyst: Y. UTSUNOMIYA

Region	Marine area of Nishinoshima						
Sample No.	Stn. 1-1-1	Stn. 1-2-2	Stn. 1-2-5	Stn. 1-2-6	Stn. 1-4-3	Stn. 1-6-3	Stn. 1-6-4
SiO_2	55.46	61.13	61.32	51.61	54.94	64.05	60.63
TiO_2	0.87	0.96	0.76	0.79	0.89	0.75	0.99
Al_2O_3	18.25	15.47	14.60	18.41	18.51	15.41	14.98
Fe_2O_3	1.43	1.43	3.88	2.16	1.88	1.32	1.93
FeO	7.18	7.49	3.45	7.34	7.11	4.95	7.44
MnO	0.19	0.23	0.07	0.20	0.17	0.20	0.22
MgO	2.99	2.39	3.08	5.28	2.71	1.69	2.41
CaO	8.80	5.31	5.99	10.39	9.05	4.05	5.87
Na_2O	3.62	4.01	5.60	2.33	3.29	4.68	3.77
K_2O	0.76	1.12	0.22	0.26	0.78	1.27	1.10
P_2O_5	0.14	0.20	0.22	0.09	0.23	0.21	0.18
H_2O^+	0.39	0.38	0.12	0.70	0.48	0.87	0.52
H_2O^-	0.14	0.21	0.11	0.32	0.17	0.19	0.20
Total	100.22	100.33	99.42	100.08	100.21	99.64	100.24
Q	6.07	14.84	13.26	4.22	7.47	18.42	15.45
Or	4.49	6.62	1.30	2.72	4.61	7.51	6.50
Ab	30.63	33.93	47.39	19.72	27.84	39.60	31.90
An	31.30	20.90	14.05	38.42	33.43	17.29	20.70
Ne	—	—	—	—	—	—	—
Di(Wo)	4.78	1.73	5.94	5.24	4.16	0.60	3.02
Di(En)	1.95	0.61	4.28	2.79	1.66	0.23	1.10
Di(Fs)	2.86	1.16	1.12	2.28	2.54	0.38	1.99
Hy(En)	5.50	5.35	4.28	10.36	5.09	3.98	4.90
Hy(Fs)	8.06	10.25	0.89	2.28	7.80	6.75	8.85
Ol(Fo)	—	—	—	—	—	—	—
Ol(Fa)	—	—	—	—	—	—	—
Il	1.65	1.82	1.44	1.50	1.69	1.42	1.88
Mt	2.07	2.07	5.63	3.13	2.73	1.91	2.80
C	—	—	—	—	—	—	—
Total	99.69	99.74	99.19	99.06	99.56	98.58	99.52

Region	Marine area of Nishinoshima			Nishinoshima-kyuto		Nishinoshima-shinto	
Sample No.	Stn. 1-9-0	Stn. 1-12-4	Stn. 2-18-5	NO-02	NO-05	NN-02	NN05
SiO_2	61.61	61.23	53.34	60.15	57.01	58.35	59.56
TiO_2	0.96	0.95	0.81	0.95	0.90	1.04	1.02
Al_2O_3	15.88	15.57	18.52	16.03	17.54	15.49	15.36
Fe_2O_3	2.69	1.40	0.38	2.30	3.92	1.43	1.86
FeO	6.07	6.76	8.53	6.18	5.14	8.23	7.73
MnO	0.22	0.21	0.18	0.22	0.18	0.22	0.22
MgO	2.24	1.89	4.07	2.33	3.01	2.66	2.65
CaO	5.28	4.65	10.43	5.67	7.56	6.17	5.54
Na_2O	3.88	4.25	2.56	4.68	3.79	4.50	3.91

Table 1. (continued)

Region	Marine area of Nishinoshima			Nishinoshima-kyuto		Nishinoshima-shinto	
Sample No.	Stn. 1-9-0	Stn. 1-12-4	Stn. 2-18-5	NO-02	NO-05	NN-02	NN-05
K_2O	1.13	1.22	0.53	1.12	0.75	1.09	1.13
P_2O_5	0.23	0.23	0.09	0.19	0.15	0.26	0.26
H_2O^+	0.09	0.89	0.68	0.33	0.24	0.27	0.43
H_2O^-	0.04	0.16	0.46	0.13	0.20	0.11	0.11
Total	100.32	99.41	100.58	100.28	100.39	99.92	99.78
Q	17.64	15.50	4.68	11.39	11.24	7.97	13.25
Or	6.68	7.21	3.13	6.62	4.43	6.44	6.68
Ab	32.83	35.96	21.66	39.60	32.07	38.08	33.09
An	22.58	19.80	37.48	19.42	28.63	18.85	21.02
Ne	—	—	—	—	—	—	—
Di(Wo)	0.88	0.74	5.71	3.12	3.30	4.20	1.99
Di(En)	0.37	0.24	2.38	1.29	1.88	1.48	0.74
Di(Fs)	0.52	0.52	3.36	1.84	1.27	2.82	1.28
Hy(En)	5.21	4.47	7.76	4.51	5.61	5.14	5.86
Hy(Fs)	7.23	9.56	10.98	6.44	3.78	9.80	10.10
Ol(Fo)	—	—	—	—	—	—	—
Ol(Fa)	—	—	—	—	—	—	—
Il	1.82	1.80	1.54	1.80	1.71	1.97	1.94
Mt	3.90	2.03	0.55	3.33	5.68	2.07	2.70
C	—	—	—	—	—	—	—
Total	100.19	98.36	99.46	99.82	99.95	99.44	99.24

Region	Nishinoshima-shinto					
Sample No.	NN-10	NN-11	NN-26	NA	NB	NC
SiO_2	58.67	58.56	58.80	58.76	59.02	58.61
TiO_2	1.03	1.04	1.05	1.01	1.03	1.00
Al_2O_3	15.65	15.63	15.83	15.32	15.53	16.17
Fe_2O_3	1.90	2.38	1.46	2.48	3.27	2.27
FeO	8.07	8.07	7.76	7.84	6.92	6.46
MnO	0.22	0.22	0.22	0.22	0.22	0.21
MgO	2.52	2.70	2.52	2.68	2.62	2.56
CaO	5.84	5.94	5.93	6.20	6.09	5.75
Na_2O	4.01	3.44	3.93	4.40	4.36	4.30
K_2O	1.12	1.13	1.13	1.07	1.06	1.07
P_2O_5	0.25	0.19	0.24	0.15	0.14	0.15
H_2O^+	0.33	0.38	0.48	0.16	0.13	0.15
H_2O^-	0.21	0.13	0.11	0.15	0.04	0.06
Total	99.82	99.50	99.54	99.52	99.97	99.50
Q	11.33	13.69	11.71	9.51	11.15	11.09
Or	6.62	6.68	6.68	6.32	6.26	6.32
Ab	33.93	29.11	33.25	37.23	36.89	36.39
An	21.39	23.87	22.22	18.89	19.67	21.66
Ne	—	—	—	—	—	—
Di(Wo)	2.48	1.82	2.35	4.55	4.02	2.46
Di(En)	0.88	0.68	0.84	1.74	1.72	1.04
Di(Fs)	1.67	1.17	1.57	2.88	2.30	1.42
Hy(En)	5.40	6.04	5.44	4.94	4.80	5.34
Hy(Fs)	10.29	10.37	10.15	8.21	6.41	7.30

Table 1. (continued)

Region	Nishinoshima-shinto					
Sample No.	NN-10	NN-11	NN-26	NA	NB	NC
Ol(Fo)	—	—	—	—	—	—
Ol(Fa)	—	—	—	—	—	—
Il	1.96	1.97	1.99	1.92	1.96	1.90
Mt	2.75	3.45	2.12	3.60	4.74	3.29
C	—	—	—	—	—	—
Total	99.28	99.30	98.87	100.13	100.26	98.55

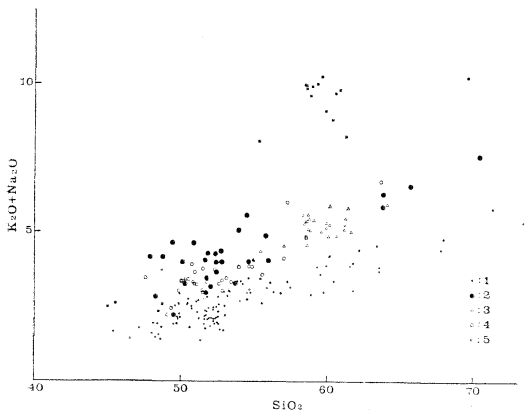

Fig. 4. Na_2O+K_2O-SiO_2 diagram for volcanic rocks from the Izu-Bonin-Mariana Islands and their associated marine area in the western Pacific.
1. Rocks from the islands from Ooshima to Kita-Yuojima.
2. Rocks from the marine area associated with the islands from Ooshima to Aogashima and Bayonnaise Rock.
3. Rocks from the Nishinoshima Islands.
4. Rocks from the northern Mariana Islands.
5. Rocks from the Yuojima Islands.

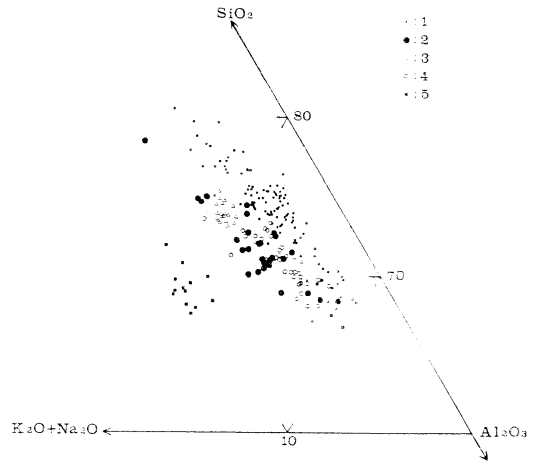

Fig. 5. Na_2O+K_2O-SiO_2-Al_2O_3 diagram for volcanic rocks from the Izu-Bonin-Mariana Islands and their associated marine area in the western Pacific. Symbols are the same as those in Fig. 4.

Marine area associated with the Izushoto Islands (KICHINA and OSTAPENKO, 1977)

Ooshima Island (TSUBOI, 1917; IWASAKI, 1935; KANI, 1939; NAGATA, 1941; TSUYA and MORIMOTO, 1951; TSUYA *et al.*, 1952; SAWAMURA, 1952; NAGASHIMA, 1953; GEOLOGICAL SURVEY OF JAPAN, 1957; KATSURA and NAKAMURA, 1960; KUNO, 1962; ISSHIKI *et al.*, 1963)

Miyakejima Island (TSUYA, 1937, 1940, 1941; HAGIWARA, 1941; KAWANO and AOKI, 1959; ISSHIKI, 1960, 1964; MATSUDA and MORIMOTO, 1962)

Mikurajima Island (TSUYA, 1937; ISSHIKI, 1980)

Hachijojima Island (TSUYA, 1937; KATSURA, 1956; KUNO, 1962; ISSHIKI, 1958, 1959, 1963)

Aogashima Island (TSUYA, 1937; ISSHIKI, 1955)

Myojinsho Reef and Bayonnaise Rocks (NIINO *et al.*, 1953; TSUYA *et al.*, 1953; HAMAGUCHI and MATSUMOTO, 1953; SUWA, 1953; MORIMOTO *et al.*, 1955; HONDA and KITANO, 1974)

Torishima Island (TSUYA, 1937; TANAKADATE, 1940b; KUNO, 1962)

Sofuiwa Rock (AOKI and OSSAKA ed., 1974)

Yuoto Islands (TSUYA, 1936; IWASAKI, 1937)

Minami-Yuojima Island (YUASA and TAMAKI, 1982)

Uracas Island (KAISER, 1903; TANAKADATE, 1940a; KUNO, 1962)

Moug Island (ISHIKAWA and EGAWA, 1977)

Agrihan Island (SCHMIDT, 1957; ISHIKAWA and EGAWA, 1977)

Pagan Island TANAKADATE, 1940a: SCHMIDT, 1957; LARSON *et al.*, 1974; ISHIKAWA and EGAWA, 1977)

Alamagan Island (SCHMIDT, 1957)

Sarigan Island (LARSON *et al.*, 1974; ISHIKAWA and EGAWA, 1977)

Anatahan Island (LARSON *et al.*, 1974; ISHIKAWA and EGAWA, 1977)

From Figs. 4 and 5, it is evident that the rocks from Yuojima Island are of alkali rock series, whereas those of Ooshima, Miyakejima, Mikurajima, Hachijojima, Aogashima, Myojinsho Reef, Torishima, Sofuiwa Rock, Kita-Yuojima Island are of low-alkali tholeiite.

Of special interest is the character of rocks dredged from the marine areas associated with the Izushoto Islands, Bayonnaise Rock and Minami-Yuojima to belong to high-alkali tholeiite and low-alkali tholeiite. Rock series of the northern Mariana Islands such as Uracas, Moug, Agrihan, Pagan, Alamagan, Sarigan and Anatahan have also been characterized by high-alkali tholeiite and low-alkali-tholeiite nare high-alkali tholeiite.

As already mentioned, the rocks of the Nishinoshima Island and their associated marine area are composed of high-alkali tholeiite and low-alkali tholeiite near high-alkali tholeiite.

4. Discussion and conclusion

There have been existed so scarce mineralogical, petrological and petrochemical data available on the seamounts and ridges in the northwestern Pacific that it was impossible to discuss their problems fully. But on the basis of the petrological and petrochemical data obtained on the islands arc and oceanic ridges, one of the writers had proposed the distinct differences between rocks of Quaternary and Tertiary ages and the subdivision of the former (AOKI, 1969, 1970).

Quaternary volcanics: RKK-Type, OMM-Type and Mixture Type

Tertiary volcanics: BSG-Type

Laterly some corrections have been made on the rocks of OMM-Type (LARSON *et al.*, 1974; ISHIKAWA and EGAWA, 1977; AOKI *et al.*, 1981; YUASA and TAMAKI, 1982).

Rocks of the northern Mariana Islands from Uracas to Anatahan are found to belong to rock series of high-alkali tholeiite distinctly different from those of low-alkali tholeiite of the Izushoto Islands (LARSON *et al.*, 1974; ISHIKAWA and EGAWA, 1977).

Based on the new data obtained from the Nishinoshima Islands and their associated marine area, the present writers had proposed the extension of high-alkali tholeiite to the Nishinoshima Islands (AOKI *et al.*, 1981). The similar conclusion is also obtained by YUASA and TAMAKI (1982).

The increase in alkalis in basaltic rocks across the Japanese arc, observed by KUNO (1959), has been related to the increasing depth to the dipping Benioff seismic zone. Hence it was expected that the difference observable in alkalis between the Izushoto Islands and the northern Mariana Islands was directly related to differences in depth to the Benioff zone beneath the two islands arcs (ISHIKAWA and EGAWA, 1977). On the contrary, LARSON *et al.*, (1974) are led to the conclusion that it presently cannot be determined whether this discrepancy in alkalis values reflects the difference in depth from the volcanic arc to the dipping seismic zone or related to other phenomena.

As far as the present knowledge is concerned, it is obvious that the rocks of marine areas associated with the Izushoto Islands are more alkalic than those of the Izushoto Islands and that the latter was emplaced on the former, in other expression, the Izushoto Islands of low-alkali tholeiite might have been formed on the basement of high-alkali tholeiite. Another explanation was expected to throw more light on the evolution of the islands arc volcanism.

Based on the above-mentioned data, the present writers have proposed the classification of volcanics in the western Pacific as follows:

a) Seamount on the trench (ED-Type, Erimo Seamount and Daiichi-Kashima Seamount, characterized by the presence of alkali rocks and so-called "continental" rocks)

b) Tertiary volcanics (BGS-Type, Bonin Islands, Saipan Island and Guam Island, characterized by the presence of calk-alkaline rock series)

c) Quaternary volcanics

Y-Type (Yuojima Island, characterized by

the presence of alkaline rocks)
OMM-MB-Type (Marine areas associated with the Izushoto Islands and Bayonnaise Rocks, characterized by the presence of high-alkali tholeiite and low-alkali tholeiite)
OMM-NMN-Type (Nishinoshima Islands, Minami-Yuojima Island and northern Mariana Islands, characterized by the presence of high-alkali tholeiite and low-alkali tholeiite near high-alkali tholeiite)
OMM-OK-Type (Islands from Ooshima Island to Kita-Yuojima, characterized by the presence of low-alkali tholeiite)

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西之島の岩石化学

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要旨：西之島（広義）は，西之島山体（海面下）・西之島旧島・西之島新島からなりたつ。

西之島山体でドレッジした岩石10個，西之島旧島で採取した２個，西之島新島で採取した８個の岩石化学的な解析をおこない，次の事を明らかにした。

1)　西之島山体・西之島旧島・西之島新島は，高アルカリソレアイト（～低アルカリソレアイト）で特徴づけられ，同一岩系に属する。

2)　西之島山体・西之島旧島・西之島新島の成分範囲(組成変化)は，前者ほどいちじるしい。

3)　北西太平洋の島弧—海溝系の火山岩は，アルカリ玄武岩・高アルカリソレアイト・低アルカリソレアイト・カルクアルカリ岩系の４岩系に分類できる。

4)　４岩系を時代別および岩系で分類すると次のとうりである。

a) 海溝上の海山(ED-Type. 襟裳海山・第一鹿島海山。アルカリ岩および大陸性岩石が存在する)

b) 第三紀火山（BSG-Type. 小笠原諸島・サイパン島・グアム島。カルクアルカリ岩系で特徴づけられる）

c) 第四紀火山

硫黄島（Y-Type. アルカリ岩系）

伊豆諸島に関連した海域およびベヨネーズ列岩（OMM-MB-Type. 高アルカリソレアイト～低アルカリソレアイト）

西之島諸島および周辺海域・南硫黄島・北マリアナ諸島（OMM-NMN-Type. 高アルカリソレアイト～低アルカリソレアイト）

伊豆諸島（OMM-OK-Type. 低アルカリソレアイト）

5)　海域に分布する火山岩は高アルカリソレアイトで特徴づけられ，これを土台にして低アルカリソレアイトの伊豆諸島が発達する。この問題に対する岩石成因論的な解釈は，今後の研究にのこされた。

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