A PRELIMINARY STUDY ON THE DISTRIBUTION OF DETRITAL GRAPHITE IN DSDP MATERIALS AND ANCIENT SEDIMENTARY BASINS

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Abstract Study of distribution of detrital graphite in sedimentary basins, such as the Pacific and the Atlantic Basins, trenches and subaqueous island arcs of the West Pacific Ocean and the Chichibu Geosynclinal Basin, suggests a non-uniform distribution of detrital graphite in these basins. On the basis of presence of detrital graphite, these basins can be primarily divided into two groups: One contains detrital graphite and the other does not. Basins lacking detrital graphite appear typically in the region between the Mariana Ridge and the Kyushu-Palau Ridge. The settling mechanism of graphite grains is discussed.

On the basis of their distribution in the ocean, the sedimentary environments of the type lacking detrital graphite can be characterized as follows: 1) Sedimentary basins sufficiently distant from stable continents and/or mature island arcs, 2) areas having a hinterland of volcanic land or arc, 3) basins at such shallow water depths as guyot and rise, 4) areas where the tectonic topography of the ocean bottom is similar to the Mariana Arc and the Kyushu-Palau Ridge. These results were used to estimate the depositional environments of the Chichibu Geosynclinal sediments. The conclusions are compatible with the results obtained from sedimentary facies analyses. It is inferred that basins of the Paleozoic South Kitakami Belt, the Hidaka Belt, a part of the Hida Marginal Belt and the Sangun Belt were a few thousand kilometers away from continents and/or had a volcanic hinterland.

Introduction

Fully-ordered graphite is very stable under conditions at the earth's surface, and is one of the minor constituent minerals in sediments, especially terrigenous sediments; however, detrital graphite in sediments has not been determined in a strict sense. TAGIRI & TSUBOI (1979) have indicated by means of the X-ray powder diffraction method that Mesozoic shales and sandstones in the Yamizo district contain detrital graphite. In this paper, the areal distribution of detrital graphite is defined in some sedimentary basins—such as, the Pacific and the Atlantic Basins, some trenches and subaqueous island arcs of the West Pacific Ocean, and the

Chichibu Geosynclinal Basin so named by KOBAYASHI (1941). The sedimentary basins are divided into two types, one type contains detrital graphite, and the other does not. It will be shown that the absence of detrital graphite is related to geotectonic environment, and, therefore, the areal distribution of detrital graphite is useful for the investigation of ancient sedimentary environments. Finally, the possible tectonic environments of a few basin in Japan are discussed on the basis of these results.

Experimental Method

Carbonaceous material was separated from fine-grained sediments. Rocks were crushed and soft sediments were used directly. About 30 cc is needed for calcareous sediments and about 15 cc for others. Calcareous sediment is first dissolved by hydrochloric acid and

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Fig. 1. The X-ray powder diffraction pattern of hole 298.

then filtered. The residue is treated with hydrochloric acid and hydrofluoric acid in a Teflon beaker on a sandbath. After dehydration, the cake is removed to a glass beaker, placed on a heater and dissolved with dilute hydrochloric acid and/or nitric acid. Nitric acid is used to dissolve sulfide minerals. The residue is a mixture of carbonaceous material and anti-hydrofluoric minerals such as zircon, garnet, tourmaline and graphite. The solution is decanted on a filter paper and most of heavy minerals are left in the beaker. The residue on a filter paper is mounted on a glass slide and placed in an X-ray diffractometer. The operating condition of the X-ray powder diffractometer were as follows; Cu-K α , 40 KV 20 mA, Ni-filter, slit 1-0.2-1 degree, range 1000 cps, time constant 1, scanning rate 1°/min, and chart speed 10 mm/min. Silicon was used as an internal standard. The presence of fully-ordered graphite is determined in terms of the d_{002} spacing of graphite (3.35—3.36)(Fig. 1). The detection limit was estimated from experiments on some samples mixed carbonaceous material with fully-ordered graphite. The detectable ratio of fully-ordered graphite to carbonaceous material is about 1:1000. Accordingly, the absence of detrital graphite means an abundance of less than 1/1000 of carbonaceous material.

Origin of Graphite : Detrital versus Diagenetic origin

LANDIS (1971) and FUJINUKI *et al.* (1974)

found fully-ordered graphite in non-crystalline carbonaceous material, but they could not specify clearly their origin. In this part, I will try to show that the graphite in sedimentary rock is detrital. It is well-known in the carbon black industry that fully-ordered graphite occurs with nearly-ordered carbonaceous matter. The d_{002} -spacing and the crystallite size of nearly-ordered carbonaceous matter are <3.43 Å and >50 Å, respectively (HONDA *et al.*, 1968). From the estimation of the detection limit, ninety-eight percent of the residue studied in this paper consists of carbonaceous material, with traces of graphite, zircon, garnet and tourmaline. All carbonaceous materials of this paper, except those from the Sanbagawa Metamorphic Belt and hornfels, are in poorly-ordered state (not in nearly-ordered state) and their d_{002} -spacing and crystallite size are >3.43 Å and <30 Å, respectively.

In this study, the fully-ordered graphite which should be defined as a detrital one by the reason described later shows a sharp peak, which results from a crystallite size of >200 Å, accompanied with a broad background of finer carbonaceous material. The fine carbonaceous material which weakly crystallizes in situ in sedimentary rocks does not show any sharp peak: for example, carbonaceous materials in rocks belonging to different metamorphic grades of Hitachi district and the meta-Paleozoic rocks of the Kitakami Mountains do not show any sharp peaks in diffraction pattern.

It is also well-known that degree of graphitization mainly depends on the temperature (e.g. FRENCH, 1964; LANDIS, 1971), though its mechanism is uncertain. The non- or weakly-metamorphosed sedimentary rocks from the Shimanto Belt usually contain fully-ordered graphite. If fully-ordered graphite crystallized in situ in sedimentary rock during diagenesis or low grade metamorphism, carbonaceous material from the higher metamorphic grades of Hitachi district and the Paleozoic rocks of the Kitakami Mountains should have transformed to fully-ordered graphite detectable by the X-ray powder dif-

fraction method. Moreover, any systematic correlation between grade of metamorphism and ratio of fully-ordered to weakly-ordered graphite is absent in the hornfelsic rock of Uwajima district.

It also appears that the extent of graphitization is not directly related to the time of duration of diagenesis: for example, fully-ordered graphite is not present in Allende carbonaceous chondrite (KIMURA, personal communication), and in weakly-metamorphosed rocks of Precambrian iron formations (FRENCH, 1964). Consequently, it seems that carbonaceous material transform to the fully-

ordered graphite detectable by the X-ray powder diffraction method at a higher metamorphic temperature about 450°C or more (e.g. FRENCH & ROSENBERG, 1965). In other words, the fully-ordered graphite does not recrystallize from carbonaceous material during the diagenesis. Accordingly, it should be better that these fully-ordered graphites in sedimentary rocks are detrital than those are in situ.

Distribution in DSDP Materials

DSDP materials were supplied by DSDP, Scripps Institution of Oceanography of the

Table 1. The distribution of detrital graphite in DSDP materials.

Sample site core interval	Locality & Depth(m)	Sediment	Age	Sedi.R.(m/m.y.)	Detrital G.	
Leg 8, 69, 2-1, 35-41	Line Is, 4978	Sil. Ooze	Mio.	5	-	
	70, 1-3, 115-122	Clipperton F.Z., 5059	Sil. Ooze	Pli.	2	+
	75, 1-2, 115-122	Tuamotu Ridge, 4181	Ter. Clay	Quart.	1	-
Leg 17, 164, 1-5, 115-122	Line Is, 5485	Zeo. Clay	Mio.	3	-	
	165, 1-1, 114-121	Central Pacific Basin, 5040	N.F. Ooze	Quart.	3	+
	166, 2-1, 56-62	Central Pacific Basin, 4950	Rad. Ooze	Pli.	2	+
	167, 2-6, 60-67	Magellan Plateau, 3166	N.F. Ooze	Quart.	9	-
Leg 20, 194, 1-2, 60-67	N.W. Pacific Basin, 5744	Silty Clay	Plei.	12	+	
	196, 2-1, 80-87	N.W. Pacific Basin, 6184	Clay	Camp.	-	-
	200, 1-6, 75-82	Ita Maitai Guyot, 1469	F. Ooze	Plei.	5	+
Leg 30, 289, 3-4, 92-98	Ontong Java Plateau, 2206	N.F. Ooze	Plei.	30	-	
Leg 31, 290, 1-4, 18-24	West Philippine Basin, 6062	Clay	Pli.	2	+	
	293, 2-3, 81-87	West Philippine Basin, 5599	Sil. Clay	Plei.	93	+
	294, 1-4, 139-146	West Philippine Basin, 5784	Clay	Plei.	3	+
	296, 1-4, 142-148	Shikoku Basin, 2920	Clay	Plei.	32	+
	297, 4-3, 43-50	Shikoku Basin, 4480	Sil. Clay	Plei.	116	+
	298, 6-2, 48-52	Nankai Trough, 4628	Sil. Clay	Plei.	343	+
	299, 3-4, 142-148	Japan Basin, 2599	Sil. Clay	Plei.	115	+
	301, 5-6, 127-134	Japan Basin, 3520	Clay	Pli.	85	+
	302, 3-4, 42-47	Japan Basin, 2399	Sil. Clay	Plei.	28	+
	Leg 32, 303, 2-3, 43-50	N.W. Pacific Basin, 5609	Di. Ooze	Pli.	16	+
306, 1-4, 59-66		Shatsky Rise, 3399	N.F. Ooze	Quart.	11	+
307, 1-4, 62-70		N.W. Pacific Basin, 5696	Clay	Plei.	10	+
308, 2-2, 56-62		Koko Guyot, 1331	Vol. Silt	0.5	-	-
310, 3-6, 55-62		Hesse Rise, 3516	N. Ooze	Pli.	6	+
311, 1-2, 71-78		N.W. Pacific Basin, 5775	Clay	Oli.	-	+
313, 1-3, 76-83		Mid-Pacific Mts., 3484	N. Ooze	Pli.	3	+
Leg 43, 386, 1-6, 144-150	Bermuda, 4783	N. Ooze	Plei.	-	+	
Leg 45, 395, 1-5, 144-150	Mid-Atlantic Ridge, 4484	N.F. Ooze	Plei.	20	+	
	396, 1-6, 138-144	Mid-Atlantic Ridge, 4450	N.F. Ooze	Plei.	13	+
Leg 56, 434A, 1-2, 102-109	Japan Trench, 5986	Clay	Plei.	40	+	
	434B, 35-1, 127-133	Japan Trench, 5986	Clay	?	40	+
	435, 1-4, 46-53	Japan Trench, 3401	Clay	Plei.	40	+
	436, 2-2, 40-47	N.W. Pacific Basin, 5240	Di. Mud	Plei.	40	+
Leg 57, 438, 3-3, 43-50	Honshu Is, 1552	Sil. Mud	Plei.	43	+	
	439, 2-1, 134-139	Honshu Is, 1656	Clay	Mio.	120	+
	439, 39-1, 38-42	Honshu Is, 1656	Shale	Creta.	-	+
Leg 59, 448, 1-1, 16-22	Palau-Kyushu Ridge, 3483	N. Ooze	Mio.	17	-	
	449, 2-1, 80-86	Parece Vela Basin, 4712	Pel. Clay	Mio.	6	+
	450, 1-1, 116-122	Parece Vela Basin, 4707	Pel. Clay	Mio.	19	+
	451, 2-3, 100-107	West Mariana Ridge, 2060	N.F. Ooze	Plei.	51	-
Leg 60 453, 2-4, 37-44	Mariana Trough, 4693	Mud	Plei.	90	-	
	454, 4-1, 83-90	Mariana Trough, 3816	Mud	Plei.	82	-
	455, 1-1, 73-80	Mariana Ridge, 3465	Mud	Holo.	121	-
	456, 6-2, 52-58	Mariana Trough, 3586	Mud	Plei.	82	-
	458, 1-3, 43-50	Mariana Ridge, 3447	Vol. Mud	Plei.	10	+
	460, 3-4, 79-85	Mariana Trench, 6452	Vol. Clay	Quart.	31	+
	461, 2-2, 52-58	Mariana Trench, 7034	Clay	Quart.	9	-

+ ; presence, - ; absence, Sil ; siliceous, Ter ; terrigenous, Zeo ; zeolitic, N. F. ; nanno foram, Rad ; radiolaria, F ; foram, Di ; diatom, Vol ; volcanic, N ; nanno, Pel ; pelagic.

University of California and the Lamont-Doherty Geological Observatory of Columbia University. Plio-Pleistocene sediments were preferentially selected, and volcanic sediments which do not contain enough amounts of carbonaceous material to be separated were excluded from the samples. 3 samples come from the Atlantic Ocean, 3 from the Japan Sea, and other samples come from the Pacific Ocean. 52 samples were tested and experiments on 48 materials were completed. The results are listed in Table 1. Localities, rock descriptions and sedimentation rates are cited from the Initial Reports of the DSDP (TRACEY *et al.*, 1971; WINTERER *et al.*, 1973; HEEZEN *et al.*, 1973; ANDREWS *et al.*, 1975; KARIG *et al.*, 1975; LARSON *et al.*, 1975; MELSON *et al.*, 1979; SCIENTIFIC PARTY, 1980; KROENKE *et al.*, 1980; HUSSORG *et al.*, in press).

Based on the distribution of detrital graphite, DSDP materials are divided into two types. In the Pacific Ocean, detrital graphite is absent from such topographic areas as ridges, rises and guyots: for example, the Tuamotu Ridge, the Ontong Java Plateau, the Koko Guyot, and the Kyushu-Palau Ridge. On the other hand, detrital graphite is found near continents and in deep basins: for example, the Japan Basin, the Shikoku Basin, the North-west Pacific Basin, the West Philippine Basin and the Parece-Vela Basin. In the Mariana Ridge region, there are areas in which detrital graphite is present and it is absent in other parts (Fig. 2). Sediments from the crest of the Mid-Atlantic Ridge contain detrital graphite. A global view of the distribution is shown in Fig. 3. The distribution pattern is not related to sedimentary facies or to sedimentation rate (Table 1).

Sedimentation Mechanism of Graphite Grains

A multitude of factors control distribution of detrital graphite in ocean basins. Graphite in these sediments seems to have a wide variety of sources; most graphite in sediments have been derived from high-grade metamorphic rocks on stable continents and mature island arcs and secondarily from graphite-bearing sedimentary rocks. Some graphite probably come from mantle or from meteorites also, but the contribution is probably insignificant. Therefore, we need not take into consideration hinterland other than stable continents and mature island arcs. All sediments near the Asian continents and the Japan Arc contain detrital graphite, for example, those in the Japan Basin, the Japan Trench, the West Philippine Basin, the Nankai Trough and the Ryukyu Basin (Fig. 2).

Three mechanisms, other than ocean currents, control the lateral transport of graphite: the first is aeolian transport, the second volcanic eruption and transport by the prevailing wind, and the third by rivers. Detrital graphite is very fine-grained (silt to clay size) and flaky, so that the first and the second mechanisms cannot be neglected

Fig. 2. The distribution of detrital graphite in DSDP materials.

Triangle ; absence, circle ; presence, arrow ; deep current at 1000 m depth, broken arrow ; bottom current proposed by Stommel.

Fig. 3. The distribution of detrital graphite in DSDP materials.
The topographic map of oceans was cited from CHASE (1975).
Triangle ; absence, circle ; presence.

as means of distribution of detrital graphite, though mass transported by these mechanisms is unknown. Graphite grains are dispersed widely on the surface of the sea by means of these mechanisms. However, the distribution of detrital graphite is not uniform in DSDP materials.

In sea water, graphite grains are carried by ocean currents, and settle on the sea bottom. For a spherical grain of quartz of clay size (0.005 mm), displacement and settling in a current of 10 cm/sec (about 0.2 knot) are 500 km and 100 m, respectively (KUENEN, 1950). Supposing the speed of the surface current equals that of a deep current, a graphite grain can move over 25,000 km before sinking to a depth of 5,000 m. The observed speed of the surface current of the Kuroshio is about 100—200 cm/sec (2—3 knot), and the speed of the deep current is less than that of the surface current. Accordingly, coarse-grained graphite settles near the hinterland, but fine-grained graphite spreads uniformly over the deep sea floor. It is expected that the dispersion in a shallow ocean basin is less uniform than that in a deep basin. Many DSDP materials from deep basins contain detrital graphite, but some DSDP materials from shallow water depths and long distances from continents, e.g., the Koko Guyot, the Magellan Plateau, the Tuamotu Ridge, the Kyushu-Palau Ridge, the Mariana Ridge and the Ontong Java Plateau, do not contain detrital graphite. Nevertheless, the absence of detrital graphite from the Mariana Trough and the Mariana Trench cannot be explained in terms of this dispersion. Most of the sediments in these basins are supplied by immature volcanic arcs, and, therefore, detrital graphite should not be expected in these basins.

Marine snow is well-known in the ocean and its sinking rate is very high, for example 40—95 m/day at shallow water depths (SHANKS & TRENT, 1980). If detrital graphite settles as marine snow, and if marine snow is common to all oceans, we must find other reasons to explain the absence of detrital graphite in some areas.

There are some deep-sea currents in the oceans (HEEZEN & HOLLISTER, 1964). Abyssal circulation is an important one (STOMMEL, 1958). The velocity of these currents ranges between 5 and 15 cm/sec (NAN'NICH & AKAMATSU, 1966; THORNDIKE & EWING, 1969; JACOBS *et al.*, 1974). The mobility of abyssal circulation is so great that fine-grained sediments on the bottom are preferentially agitated and transported over long distances to deeper bottom by deep-sea currents (HEEZEN & HOLLISTER, 1964). As a consequence, detrital graphite is distributed uniformly along areas of abyssal circulation. Many deep-sea currents exist around the Mid-Atlantic Ridge (WÜST, 1957), which explains the presence of detrital graphite on the crest of the Mid-Atlantic Ridge. On the basis of the abyssal circulation model of STOMMEL (1958) and the observation on deep-sea currents in the region of the Mariana Ridge (NAN'NICH & AKAMATSU, 1966), deep-sea currents at 1000–2000 m depth flow from north to southeast, and those at greater depth from south to northeast on the east-side of the Mariana Arc (Fig. 2). It is probable that detrital graphite does not disperse uniformly along the western side of the Mariana Trench or on the ocean slope of the Mariana Trench.

The presence of detrital graphite is expressed in terms of its ratio to organic matter. If the biological production and settling is fast in the ocean, the ratio becomes so small that graphite cannot be detected by means of the X-ray powder diffraction method. For example, detrital graphite cannot be detected in coal, but some fossiliferous limestones contain. The biological production in the ocean near the Mariana and Kyushu-Palau Ridges is less than that of the North Pacific Basin (GESSNER, 1959; LISITZIN, 1972). Accordingly, the absence of detrital graphite cannot be explained only in terms of the biological production. The absence of graphite is due to more than one of the mechanisms discussed above.

Graphite Distribution in Some Sedimentary Basins of Japan

Some sedimentary basins in 15 tectonic regions were tested for the presence of detrital graphite. The basins cover a wide range in time, from Silurian to Tertiary. The results are listed in Table 2. The sampling localities are indicated in Fig. 4 together with the pre-Neogene tectonic divisions compiled by the GEOLOGICAL SURVEY OF JAPAN (1977). Ancient sedimentary basins are also divided into two types with regard to detrital graphite. The geology of these divisions from northeast to southwest are described briefly as follows.

Hidaka Belt: The low-pressure Hidaka Metamorphic Rocks crop out in this belt. The original rocks of most of the metamorphics were pre—Early Cretaceous clastic rocks (Hidaka Supergroup) (HASHIMOTO, 1958; HASHIMOTO & TAKEDA, 1960; KONTANI, 1978). They were derived from acidic volcanic and sedimentary terranes (KONTANI, 1980). Samples were collected near Biroo

Fig. 4. Pre-Neogene tectonic divisions of Japan and the distribution of detrital graphite.

1 ; Hida Belt, 2 ; Sangun Belt, 2m ; Maizuru Structural Belt, 2' ; Hida Marginal Belt, 2'' ; Joetsu Belt, 3 ; Tamba Belt, 3' ; Ashio Belt, 4 ; Ryoke Belt, 5 ; Sanbagawa Belt, 6 ; Chichibu Belt, 7 ; Sanbosan Belt, 8 ; Shimanto Belt, 9 ; Ainoshima Belt, 10 ; Nishisonogi Belt, 11 ; Tsushima Belt, 12 ; Abukuma Belt, 13 ; South Kitakami Belt, 14 ; North Kitakami Belt, 15 ; Iwaizumi Belt, 16 ; Taro Belt, 17 ; Ishikari Belt, 18 ; Kamuikotan Belt, 19 ; Hidaka Belt, 20 ; Tokoro Belt, 21 ; Nemuro Belt. Broken line which goes through the central part of Shikoku and Kyushu represents Kurosegawa Structural Belt.

Table 2. The distribution of detrital graphite in some ancient sediments of Japan. Numerals mean the number of samples.

Tectonic Division	Group or District	Geologic Time	Absence	Presence
Hidaka	Yezo G.	Creta.	3	0
Kamuikotan	Nakanogawa G.	pre-Creta.	7	0
	Sorachi G.	pre-Creta.	0	3
	Kamuikotan G.	pre-Creta.	4	4
South Kitakami	Kukunari F.	Jura.	0	1
	Hiraiso F.	Trias.	0	1
	Saragai F.	Trias.	0	1
	Osawa F.	Trias.	0	1
	Toyoma F.	Perm.	2	0
	Iwaizaki F.	Perm.	1	0
	Kanokura F.	Perm.	3	0
	Sakamotozawa F.	Perm.	5	0
	Karaumedate F.	Carbon.	1	0
	Tobigamori F.	Devon.	0	1
	Kawauchi F.	Siluri.	1	0
	Hitachi G.	Carbo-Perm.	3	0
	Yamizo G.	Trias.	0	many
	Adoyama F.	Trias.	0	3
Abukuma	Ashigara G.	Tert.	3	0
Ashio				
Tanzawa Mts.				
Hida Marginal	Omi dist.	Perm.	3	2
	Fukuji dist.	Carbon.	1	1
		Devon.	2	0
		Carbon.	2	0
Tamba	Kuzuryu dist.	Trias.	0	1
	Mino dist.			
Sanbagawa	Kannagawa dist.	Perm-Trias.	3	0
	Asenigawa dist.	Perm-Trias.	0	many
	Oshika dist.	Perm-Trias.	2	2
Chichibu	Oshika dist.	Perm-Trias.	0	1
Sanbosan	Unomachi dist.	Trias-Jura.	0	3
Shimanto	Uwajima dist.	Creta.	1	7
	Wakayama dist.	Creta.	0	2
Maizuru Struct.	Maizuru G.	U-Paleozoic	0	2
Sangun	Taishaku G.	Perm.	5	1
Kurosegawa	Yokokurayama dist.	Siluri.	1	0

and supplied by Dr. KONTANI.

Kamuikotan Belt: This belt is characterized by the distribution of the high-pressure Kamuikotan Metamorphic Rocks which were derived from mafic volcanic rocks, chert and mudstone (HUNAHASHI, 1958). The Cretaceous Yezo Group is included in the belt (MATSUSHITA & SUZUKI, 1962; KANIE, 1966). The sampling was done in the Noya, Urakawa, Shizunai and Asahikawa districts.

South Kitakami Belt: This belt is composed of Paleozoic and Mesozoic strata intruded by many Cretaceous granitic rocks. The Paleozoic sedimentation ranges in age

from Silurian to Permian. The Paleozoic system is dominated by limestone and clastic rocks including some volcanic rocks, and the Mesozoic system by clastic rocks (ONUKI, 1969). The provenance of the Paleozoic sediments is from basic volcanic and sedimentary terranes (KATADA & ONO, 1978). On the basis of the chemical character of the Paleozoic volcanic rocks, it is thought that the South Kitakami Belt was a Paleozoic island-arc (KANISAWA, 1971; KAWABE *et al.*, 1979).

Abukuma Belt: The Abukuma Metamorphic Rocks and the Hitachi Metamorphic Rocks develop in this belt (MIYASHIRO, 1958; TAGIRI, 1973). Moreover, the belt is characterized by the predominance of Cretaceous granitic rocks. Samples were collected from the Hitachi district. The Hitachi Metamorphic Rocks, which were derived from volcanic rocks with subordinate clastic rocks, includes Carboniferous and Lower Permian formations. The sedimentary rock facies are analogous to those of the Paleozoic South Kitakami Belt. The petrographic and chemical character of volcanic rocks belong to the volcanic rock series of the island-arc type (TAGIRI & OKURA, 1979).

Ashio Belt: This belt is composed of Upper Paleozoic to Lower Mesozoic clastic rocks with subordinate limestone, chert and volcanic rocks (KOIKE *et al.*, 1974; YOSHIDA *et al.*, 1976). The belt is thought to be a part of the Tamba Belt. The sampling was done in the Yamizo Mountains (TAGIRI & TSUBOI, 1979) and the Kuzuu district.

Tanzawa Mountains: This belongs to the district of Neogene tectonism and is characterized by the low-pressure Tanzawa Metamorphic Rocks which were mainly derived from volcanic rocks. The age of the original sedimentation is from Miocene to Pliocene. Meta-volcanic rocks of the calc-alkali rock series are involved (SEKI *et al.*, 1969) and this region including the Izu Peninsula was an island-arc in Miocene age.

Hida Marginal Belt: This belt consists of the high-pressure Omi-Renge Metamorphic rocks, Siluro-Devonian strata, Permo-Carboniferous strata of limestone with subordinate

clastic and volcanic rocks and Lower Jurassic sediments. Samples were gathered from Siluro-Devonian strata and Permo-Carboniferous strata in the Omi (KAWADA, 1954; CHIHARA *et al.*, 1979), the Fukuji (KAMEI 1952; IGO, 1956) and the Kuzuryu (KAWAI *et al.*, 1957) districts.

Tamba and Ryoke Belts: The sedimentary facies of these belts are characterized by the predominance of clastic rocks with subordinate chert and volcanic rocks. Most of the sediments belong to the Triassic and the Permian. The low-pressure Ryoke Metamorphic Rocks crop out in these belts and are thought to grade stratigraphically into the non-metamorphic rocks of the Tamba Belt (KANO, 1978). The provenance of the Mesozoic sediments is a plutonic terrane (ADACHI, 1976; KATADA & ONO, 1978). A sample was collected near Hirayu (IGO, 1956).

Sanbagawa Belt: This belt consists of the high-pressure Sanbagawa Metamorphic Rocks which were derived from Upper Paleozoic to Lower Mesozoic volcanic and clastic rocks (KOJIMA, 1951; BANNO, 1964). These metamorphic rocks are thought to change stratigraphically into the weakly metamorphosed sediments of the Chichibu Belt described later. The sampling was done in the Oshika (WATANABE, 1977) and the Kannagawa districts (TORIUMI, 1975). The data for the Asemigawa district were cited from ITAYA (1981).

Chichibu Belt: This belt is composed of Lower Carboniferous to Triassic clastic rocks, chert, limestone and mafic volcanic rocks which are weakly metamorphosed. The provenance is an acidic volcanic terrane (KATADA & ONO, 1978). The sampling was done in the Oshika district (WATANABE, 1977).

Sanbosan Belt: This belt is composed of Middle Permian to Early Jurassic limestone, chert and mafic volcanic rocks. The belt is thought to have formed arc islands at that time (KIMURA, 1973). Samples were collected from the Unomachi district.

Shimanto Belt: This belt consists of Late Mesozoic to Early Tertiary strata, the rock

facies of which are different in the northern and the southern sub-belts. Chert and submarine mafic volcanic rocks are predominant in the northern sub-belt. The southern sub-belt is dominated by clastic sediments. The provenance is plutonic and acidic volcanic terranes (TERAOKA, 1977). Samples were collected in the Uwajima district (TERAOKA, 1979), and those from the Wakayama district were furnished by Dr. OCHIAI.

Maizuru Structural Belt: This belt is characterized by the Yakuno mafic-ultramafic rocks which involve the ophiolitic complex (ISHIWATARI, 1978). The complex was intruded into Permian to Triassic strata. Samples of the Oi district were offered by Dr. ISHIWATARI.

Sangun Belt: This belt is characterized by the distribution of the high-pressure Sangun Metamorphic Rocks. Weakly metamorphosed Paleozoic rocks consisting of limestone, clastic rocks, chert and mafic volcanic rocks are widely developed in the belt (HASHIMOTO, 1966; HASE *et al.*, 1974). The provenance is uncertain. Moreover, Mesozoic strata are included. Samples of the Taishaku-dai area were supplied by Dr. NISHIMURA (NISHIMURA *et al.*, 1979).

Kurosegawa Structural Belt: This belt is included in the Chichibu Belt and consists of pre-Silurian high-grade metamorphic rocks, Silurian to Devonian strata and Silurian granitic rocks (ICHIKAWA *et al.*, 1956). A sample was collected at Mt. Yokokura (NODA, 1955). KIMURA (1973) stated that this belt was an older inner arc of Paleozoic age.

Possible Environments of Some Ancient Sedimentary Basins

On the basis of the distribution of detrital graphite in the ocean, the sedimentary environments in which detrital graphite does not settle seem to be as follows: 1) Sedimentary basins sufficiently distant from stable continents and/or mature island arcs, 2) basins having a hinterland of volcanic land or arc, 3) areas of shallow water depth such as guyots and rises distant from stable continents and/or mature island arcs, 4) areas with

topographic characters analogous to the Mariana Arc and the Kyushu-Palau Ridge, which are located in the western part of ocean, distant from continents and mature island arcs, and are active volcanic chains. These results can be applied to estimate the environments of ancient sedimentary basins.

In the South Kitakami Belt, the Paleozoic rocks from Silurian to Permian do not contain detrital graphite. When the sediments lacking detrital graphite are supplied to one basin for a long time, its sedimentary environment may be invariable and probably belongs to all of the four types mentioned above. In the case of the sedimentation over a short period such as the Tanzawa Mountains, the environment is of the second or the third type. The Paleozoic stage of the South Kitakami Belt and the Hitachi district is thought to have been a volcanic island arc (KANISAWA, 1971; KIMURA, 1973; TAGIRI & OKURA, 1979), which is compatible with these results. Moreover, the basin of these districts must have been situated far away from continent and/or mature island arc. Sedimentary rocks of the Hidaka Belt, too, were located in such environment. The basins of the other districts studied in this report cannot be specified from the distribution of detrital graphite, but it is possible that parts of the Sangun Belt, the Hida Marginal Belt and the Kamuikotan Belt are of the type of basin lacking detrital graphite.

KATADA and ONO (1978) discussed source rocks of sandstone and mudstone in the Honshu (Chichibu) Geosyncline from the modal and chemical analyses. Though they do not characterize tectonic topography for those basins, their discussions were concordant with the present result, except for the Sangun Belt. The tectonic history of the Japanese Islands has been discussed by many authors (e.g., KOBAYASHI, 1941; MINATO *et al.*, 1965; ICHIKAWA *et al.*, 1972; KIMURA, 1974; SUZUKI *et al.*, 1979). These histories are based on some indices of the tectonic movement as follows: Sedimentary rock facies, metamorphic facies series, volcanic rock series and acidic magmatism. The sedimentary basins

of the Japanese Islands have almost always been located near the Asian continent and thus their hinterland was a stable continent. The history must also be considered from the point of view of the distribution of detrital graphite. The Paleozoic South Kitakami Belt, the Hidaka Belt, a part of the Kamuikotan Belt, a part of the Hida Marginal Belt and a part of the Sangun Belt were probably once basins lying a few thousand kilometers from a continent, and/or these hinterlands were volcanic lands. These basins are not equivalent to the Japan Basin, the Japan Trench, the Nankai Trough and the Shikoku Basin.

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DSDP 試料及び堆積盆中の碎屑性石墨の分布

田 切 美 智 雄

(要 旨)

太平洋と大西洋の海盆や、西太平洋の海溝、島弧、秩父地向斜などの堆積盆中の碎屑性石墨の分布を調べた。石墨粒子は、いくつかの堆積盆では均一な分布を示さない。碎屑性石墨の有無によって、堆積盆は2大別できる。碎屑性石墨を含まない堆積盆は、マリアナ海嶺と九州—パラオ海嶺にはさまれた地域で、特徴的である。石墨粒子の堆積機構を考察し、石墨粒子堆積の有無は、いくつかの要因が複雑に重なってあらわれることを示した。

海洋中の石墨分布にもとづくと、石墨を堆積しない堆積環境として、次の四つの場合がある。1) 安定大陸や成熟した島弧から十分離れた堆積盆。2) 後背地として火山性陸地や火山性島弧を持つ場合。3) ギョーや海膨のような浅い堆積盆。4) マリアナ弧や九州—パラオ海嶺に似た構造地形の堆積盆。これらの考察をもとに、秩父地向斜堆積物の堆積環境の推定を試みた。結果は、堆積岩の岩

相解析から得られる推察と矛盾しない。碎屑性石墨が分布しない、古生代の南部北上帯や、日高帯、飛騨外縁帯の一部、三郡帯の一部の堆積盆は、大陸から数千 km 離れていたか、もしくは、火山性後背地を有していたと推察される。

(地 名)

Asahikawa	旭川	Omi	青海
Asemigawa	汗見川	Oshika	大鹿
Birou	広帯	Shizunai	静内
Fukuji	福地	Taishakudai	帝釈台
Hirayu	平湯	Unomachi	卯ノ町
Kannagawa	神流川	Uwajima	宇和島
Kuzuryu	九頭竜	Wakayama	和歌山
Kuzuu	葛生	Yokokura	横倉
Noya	農家	Yamizo	八溝
Oi	大飯		