J. Earth Planet. Sci. Nagoya Univ., Vol. 49, 15 to 30, 2002

Permo-Triassic and Early-Middle Jurassic granitoid clasts from the Jurassic conglomerates in the Mino terrane, central Japan

Shiro TANAKA[1], Yusei KUROYANAGI[2], Kazuhiro SUZUKI[3] and Mamoru ADACHI[4]

[1]*Department of Earth and Planetary Sciences, Graduate School of Sciences, Nagoya University, Chikusa-ku, Nagoya 464-8602, Japan*
[2]*Japan Petroleum Exploration Corporation, 2-2-20 Higashi-shinagawa, Shinagawa-ku, Tokyo 140-0002, Japan*
[3]*Center for Chronological Research, Nagoya University, Chikusa-ku, Nagoya 464-8602, Japan*
[4]*The Nagoya University Museum, Nagoya University, Chikusa-ku, Nagoya 464-8601, Japan*
(Received December 10, 2002 / Accepted December 25, 2002)

ABSTRACT

CHIME (chemical Th-U-total Pb isochron method) has been applied to determine the ages of seven granitoid clasts (5 granite, 1 mylonitized granite and 1 granodiorite) in the Jurassic Ohgitani, Bandokoro and Tsukiyozawa conglomerates in the Mino terrane, central Japan. CHIME dating is also applied to detrital zircons in the Jurassic sandstone in the vicinity of the Ohgitani conglomerate and matrix sandstone of the Ohgitani conglomerate. Results of CHIME show that the monazites from the three granite clasts yield isochron ages of ca. 250 Ma (259±7 Ma, 245±4 Ma and 228±39 Ma). Apparent CHIME zircon ages of the other 2 granite and 1 mylonitized granite clasts also show ca. 250 Ma. On the other hand, monazites in a granodiorite clast indicate younger isochron age of ca. 180 Ma than the other granitoid clasts. The CHIME ages from the granitoid clasts indicate emplacement of ca. 250 Ma granites and ca. 180 Ma granodiorite.

Detrital zircons from the Jurassic sandstone yield ages ranging from 2031 to 183 Ma, and some age data gathered ca. 250 Ma. The CHIME ages of detrital zircon suggest that Proterozoic (ca. 2000 Ma), Paleozoic (ca. 450, 350 and 250 Ma) and Early-Middle Jurassic (ca. 180 Ma) thermal events in a provenance of Jurassic clastic rocks of the Mino terrane.

Both results from the granitoid clasts and sandstones especially suggest ca. 250 and 180 Ma igneous activities in the provenance of the Mino terrane. Occurrence of ca. 250 and 180 Ma granitoid reminds us of igneous activity at eastern margin of the Asian continent, and the Hida terrane which is continental affinity in the Japanese islands.

INTRODUCTION

Suzuki et al. (1991) and Adachi and Suzuki (1994) have reported a large number of CHIME (chemical Th-U-total Pb isochron method: e.g. Suzuki et al., 1991; Suzuki and Adachi, 1991a, 1991b; Suzuki et al., 1999) ages of detrital monazite and zircon from Jurassic sandstone in the Mino terrane, central Japan. Despite numerous chronological analyses for detrital minerals (e.g. Suzuki et al., 1991), knowledge about the types

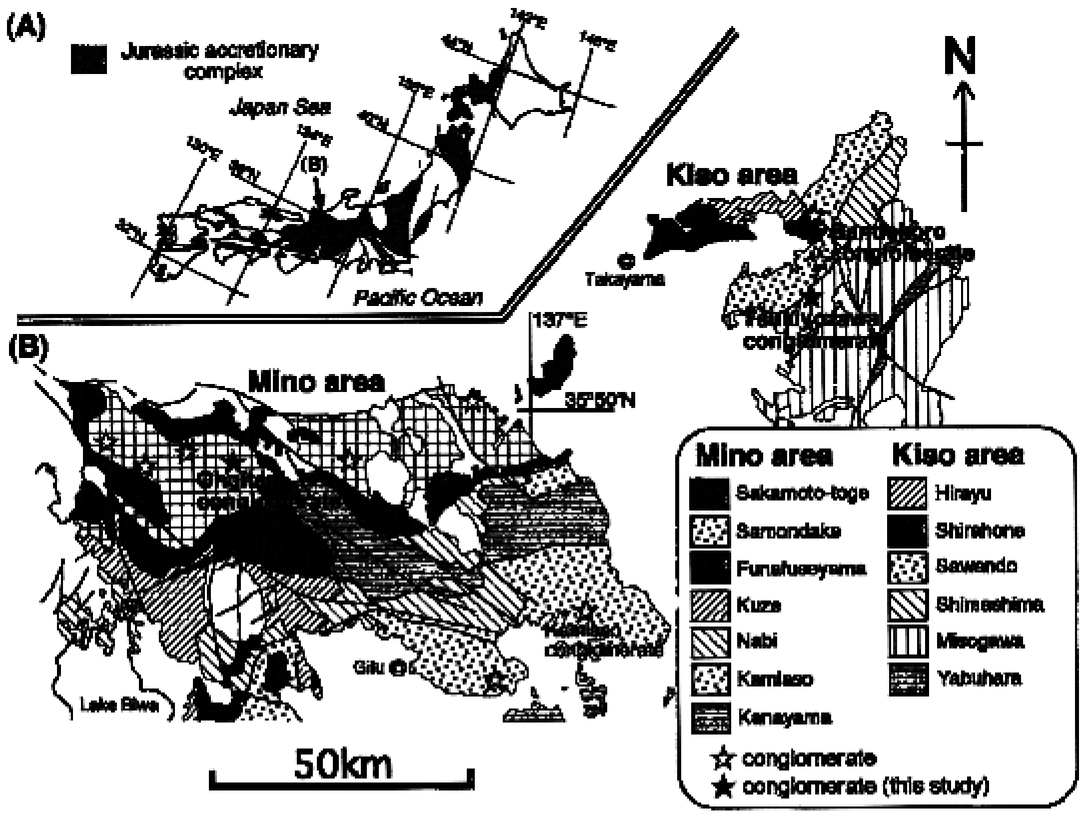

Fig. 1. (A) Distribution of Jurassic accretionary complexes in the Japanese islands, and (B) distribution and subdivision of the Mino terrane (modified from Wakita, 1988; Otsuka, 1988; Nakae, 2000; Wakita et al., 2001). Star symbols show the localities of Jurassic conglomerates.

of source rocks for the Jurassic sediments is scant. Their data indicate that Proterozoic to Mid-Jurassic metamorphic rocks and igneous rocks are included in the provenance of Mino terrane sediments.

In the Jurassic sandstone, intraformational conglomerates that contain granitoid and gneiss clasts are present (Fig. 1; e.g. Kanuma and Irid, 1962; Tanaka et al., 1952; Adachi, 1971; Hattori et al., 1985; Otsuka, 1985, 1988, Nakano et al., 1995). Clasts of Proterozoic metamorphic rocks have also been reported from the conglomerates in the Mino terrane (e.g. Shibata and Adachi, 1974; Adachi and Suzuki, 1993; Tanaka et al., 2002). This paper especially focuses on CHIME ages of monazite and zircon from unknown age of granitoid clasts identified in the Jurassic conglomerates, Mino terrane.

GEOLOGICAL SETTING

The Mino terrane of central Japan is a Jurassic to early Cretaceous accretionary complex (e.g. Otsuka, 1988; Wakita, 1988) that is composed of greenstone, limestone, chert, siliceous shale, shale, sandstone and conglomerate. Similar complexes occupy a large area of Southwest Japan and extend north to Sikhote-Alin and northeast China (Fig. 1; Kojima, 1989). The Mino terrane is subdivided into several geological units (complexes) on the basis of lithology, age and structure (Fig. 1; Otsuka, 1988; Wakita, 1988; Nakae, 2000; Yamakita and Otoh, 2000). Otsuka (1988) and Wakita (1988) provide detailed geological features of these units.

In this study, specimens were collected from the Ohtagiri conglomerate (described in Hattori et al., 1985), the Bandokoro conglomerate (described in Otsuka, 1985) and the Tsukiyozawa conglomerate (described in Tanaka et al., 2000). All conglomerates are poorly sorted, matrix-supported, polymict and intraformational (Fig.2).

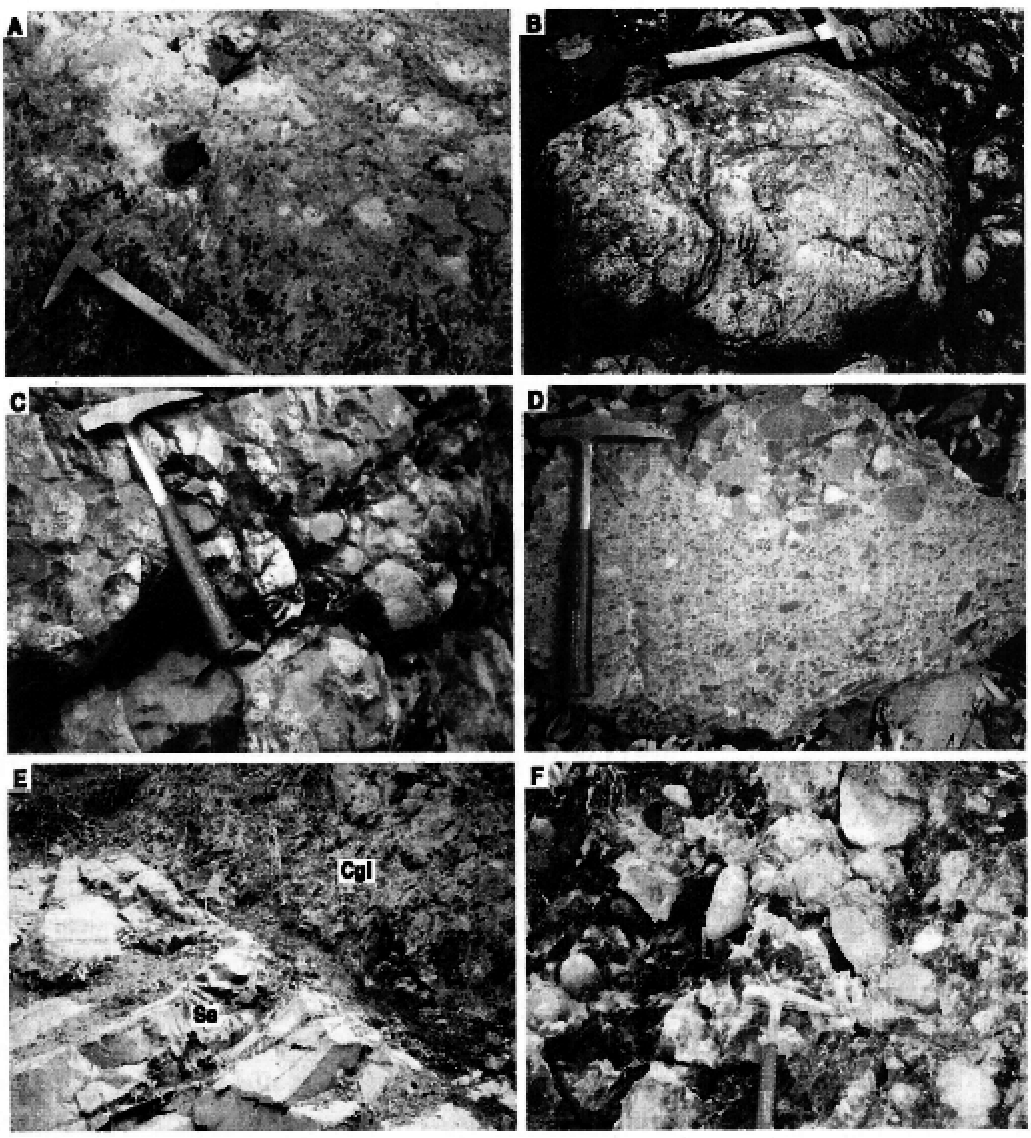

Fig. 2. Outcrops of conglomerate. A: Ohgitani conglomerate. This conglomerate contains subrounded clasts of granitoid, sandstone and chert, and shale patches. B: Subrounded granitic bounder (70 cm in diameter) in the Ohgitani conglomerate. C: Poorly sorted and matrix supported facies of the Bandokoro conglomerate. D: Pebble to cobble conglomerate has eroded shale patch-rich granule conglomerate at the Bandokoro conglomerate. E: Alternating beds of conglomerate (Cgl), and massive and coarse-grained sandstone (Sst). F: Close-up view of the Tsukiyozawa conglomerate.

Ohgitani conglomerate

Hattori et al. (1985) included this lithology in the Kanmuriyama Conglomerate group. The Ohgitani conglomerate is located in the Samondake Unit (Wakita, 1988), and contains clasts of sandstone, shale, chert, limestone, acidic volcanic rocks, granitoid, gneiss and orthoquartzite. Radiolarian fossils from the Samondake Unit (e.g. Kobayashi, 1998) provide a Middle Jurassic age for sedimentation of coarse-grained clastic rocks.

Bandokoro conglomerate

This conglomerate in the Sawando complex (Otsuka, 1988) is described in Otsuka (1985, 1988). It consists of clasts of sandstone, shale, chert, limestone, marl, acidic volcanic to hypabyssal rocks, granitoid, gneiss and orthoquartzite. A few limestone clasts contain Carboniferous and Permian fusulinids. Radiolarian fossils (Otsuka, 1988) indicate that deposition of coarse-grained clastics occurred in the late Middle Jurassic.

Tsukiyozawa conglomerate

This conglomerate in the Misogawa complex (Otsuka and Watanabe, 1992) is described in Otsuka (1988), Nakano et al. (1995) and Tanaka et al. (2000). This conglomerate contains clasts of sandstone, shale, chert, acidic volcanic to hyperbyssal rocks, granitoid, gneiss and orthoquartzite clasts. Limestone and marl clasts are absent. Radiolarian fossils (Otsuka, 1988; Okumura and Otsuka, 1996) provide a Late Jurassic age for sedimentation age of coarse-grained clastic rocks.

CHIME AGE ANALYSIS

Monazite and zircon grains in polished thin sections were analyzed on a JEOL JCXA-733 electron-probe microanalyzer. Accelerating voltage, probe current and probe diameter were 15 kV, 0.2μA and 5μm, respectively. The ThMα, UMβ, PbMα and YLα lines were measured simultaneously with PET crystals. The standards were euxenite provided by Smellie et al. (1978) for Th and U, and synthesized glass (10.8% PbO; Suzuki and Adachi, 1998) for Pb. X-ray intensities were integrated over 300 seconds by 5-times cyclic stepping of spectrometers on individual peak and background positions. The measurements were repeated twice, and arithmetic averages were taken. The spectral interference of YLγ on PbMα was corrected with the method described by Åmli and Griffin (1975). The X-ray intensity data were converted into concentrations with the Bence and Albee (1968) method, using analyses of natural zircon and monazite as matrix compositions (Suzuki et al., 1999), since small differences in the matrix between analyzed and reference minerals have little effect on ThO_2, UO_2 and PbO determinations. The detection limits at 1σ confidence level are 0.007, 0.011 and 0.003wt.% for ThO_2, UO_2 and PbO, respectively. The relative errors are about 30% for 0.01 wt.% of PbO concentration, 6% for 0.3 wt.% of UO_2 concentration, and 1% for 10 wt.% of ThO_2 concentration. The details of the analytical procedure and the CHIME age calculation are described in Suzuki and Adachi (1991a) and Suzuki et al. (1991).

ANALYZED SAMPLES

Granite clasts
YK91042703F, KS89081301, YK91053001C, YK91042603I
[Ohgitani conglomerate]

The Ohgitani conglomerate includes clasts of medium-grained leucocratic granite, which consist chiefly of quartz, plagioclase, potassium feldspar and biotite with small amounts of muscovite and opaque minerals, along with secondary chlorite, calcite and muscovite. Zircon, apatite, rutile, allanite, monazite and garnet occur in accessory amounts. Some plagioclase grains are strongly sericitized, and some potassium feldspar grains are weakly sericitized. Potassium feldspar has perthite and/or microcline textures. Some potassium feldspar grains, 6-15 mm across, are poikilitic and contain inclusions of plagioclase, quartz and biotite. Plagioclase grains are subhedral, quartz and potassium feldspar grains are anhedral and fill interstices between plagioclase grains. Myrmekites are sometimes observed in plagioclase grains. Calcite pseudomorphs after hornblende or pyroxene occur in sample YK910162703F (Fig. 3-A), and contain inclusions of quartz, apatite and chlorite. Sample YK91053001C is a mylonitized granite clast (Fig. 3-B).

ST96101703 (2) [Bandokoro conglomerate]

This specimen is a round clast over 50 cm in diameter. It consists largely of quartz (46%), potassium feldspar (perthite; 27%), plagioclase (21%), chloritized biotite (6%) and minor amounts of apatite, opaque minerals, zircon, monazite and allanite (Fig. 3-C). Monazites occur as euhedral to subhedral grains 200 μm across, and are associated with biotite and allanite (Figs. 3-E, F and G). Back-scattered electron (BSE) images of analyzed monazites typically show concentric oscillatory zoning (Figs. 4-A, B and C).

Granodiorite clasts
ST96101905 [Tsukiyozawa conglomerate]

This specimen is of a round clast 12 cm in diameter and is of porphyritic biotite granodiorite (Fig. 3-D). It is mainly composed of plagioclase (39%), quartz (28%), potassium feldspar (microcline; 15%) and biotite (17%) and minor amounts of apatite, opaque minerals, zircon and monazite. Plagioclase (An% is 40-46%) is partially replaced by sericite. Some potassium feldspars are porphyritic (over 1 cm in size) and have a weak preferred orientation. Monazite typically occurs in association with biotite flakes (Figs. 3-H, I and J). Monazite grains are euhedral to subhedral, and are from 130 to 380 μm across. BSE images of analyzed monazites show dappled contrast patterns (Figs. 4-D, E and F).

Sandstone
YK91042601A, YK91042705D [Massive sandstone in the Ohgitani area]

Massive sandstones near the Ohgitani conglomerate are generally quartzo-feldspathic wackes containing patches of shale. These massive sandstones are essentially composed of quartz, plagioclase, potassium feldspar, calcite, rock fragments, detrital heavy minerals, and a clayey matrix. Rock fragments include granitic rocks, acidic volcanic rocks, mudstone, sandstone, chert, basaltic rocks, mylonitic rocks and mus-

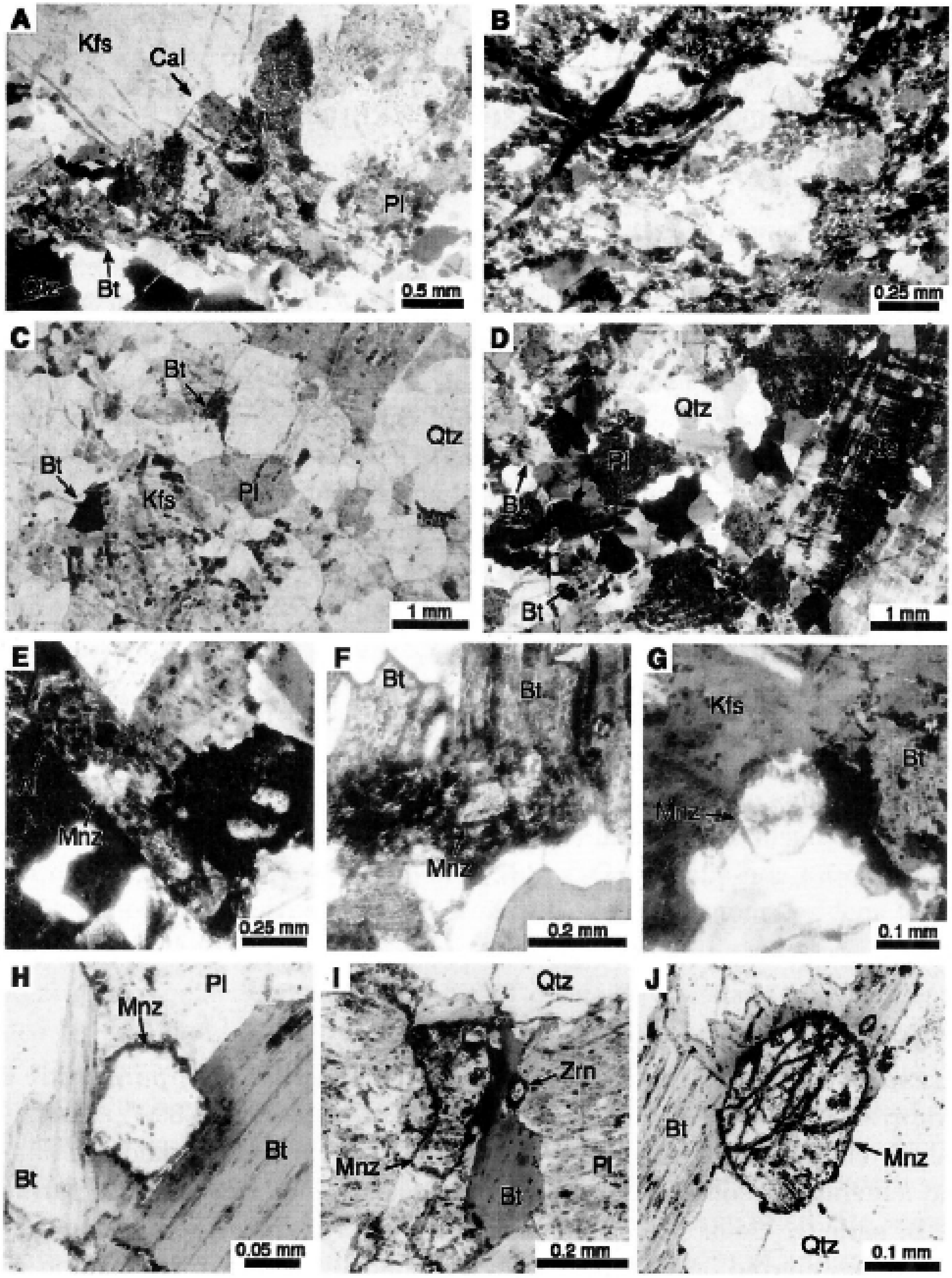

Fig. 3. Photomicrographs of analyzed granitoid clasts. A: Granite clast (sample YK91042703F) from the Ohgitani conglomerate. Calcite (Cal) pseudomorph after pyroxene or hornblende. XPL. B: Mylonitic texture in granite clast (sample YK91053001C) from the Ohgitani conglomerate. XPL. C: Texture in granite clast (sample ST96101703(2)) from the Bandokoro conglomerate. PPL. D: Texture in granodiorite clast (sample ST96101905) from the Tsukiyozawa conglomerate. Porphyritic microcline showing Carlsbad twin with many inclusions (mainly quartz). XPL. E-G: Analyzed monazite grains from the sample ST96101703 (2). E: Subhedral monazite is surrounded by euhedral allanite. XPL. F: Subhedral monazite in biotite. XPL. G: Euhedral monazite with opaque mineral in K-feldspar. XPL. H-J: Analyzed monazite grains in the sample ST96101905 occur with biotite; pleochroic halo is common. Monazite (H) shows analyzed spots (small dots) for CHIME dating. PPL. Abbreviations in photomicrographs are Al: allanite, Bt: biotite, Cal: calcite, Kfs: K-feldspar, Mnz: monazite, Pl: plagioclase, Qtz: quartz, Zrn: zircon. PPL: parallel polarized light. XPL: crossed polarized light.

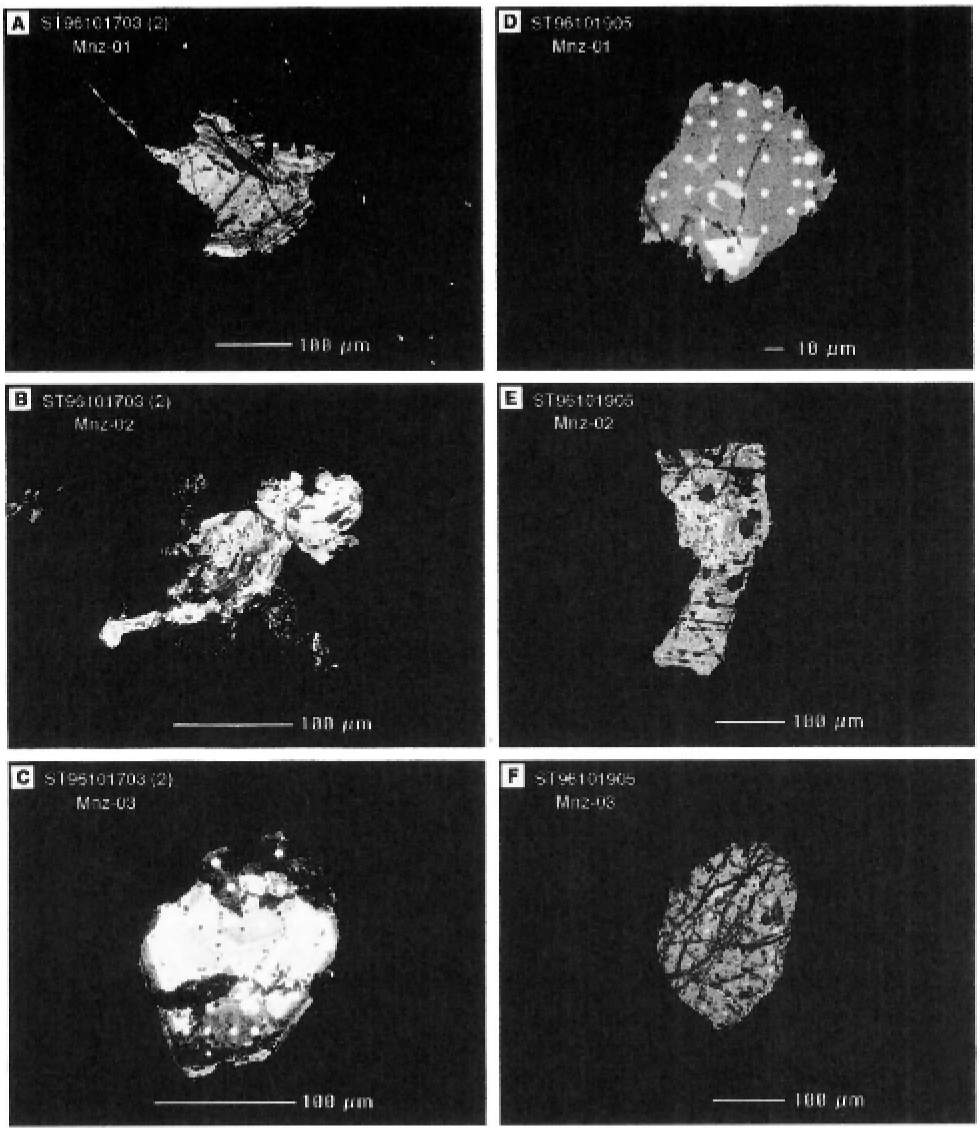

Fig. 4. Back scattered electron (BSE) images of analyzed monazite from the granitoid clasts. A, B and C: Monazite from sample ST96101703(2), a granite clast from the Bandokoro conglomerate. These BSE images show oscillatory zoning. D, E and F: Monazite from the granodiorite clast (sample ST96101905) from the Tsukiyozawa conglomerate. These BSE images show dappled contrast patterns. Light spots are analysis sites for CHIME dating

covite-quartz schist. Detrital minerals include large amounts of garnet, zircon and apatite, along with small amounts of biotite, muscovite, chlorite, titanite, rutile, allanite and opaque minerals.

KS89081302 [Matrix sandstone of Ohgitani conglomerate]

The matrix of the Ohgitani conglomerate is a lithic wacke sandstone with shale patches that are generally 1 to 3 cm long (maximum 25 cm). It is mainly composed of angular to subangular grains of quartz, plagioclase, potassium feldspar, rock fragments, and a clayey or calcite-rich matrix. Rock fragments include granitic rocks, acidic volcanic rocks, chert, sandstone, mudstone, basaltic rock and muscovite-quartz schist, and are generally 1 to 3 mm in size (up to 20 mm). Detrital heavy minerals include garnet, zircon, apatite, biotite, muscovite, chlorite, titanite, allanite and opaque minerals. Potassium feldspar grain has a perthite or microcline structure.

Table 1. Representative analytical data of monazite and zircon from the granitoid clasts and sandstones in the Mino terrane.

Sample. Grain No.	ThO_2 (wt.%)	UO_2 (wt.%)	PbO (wt.%)	Age# (Ma)	ThO_2* (wt.%)
ST96101905 [Granodiorite clast]					
Mnz01-01	9.24	0.376	0.074	168	10.45
Mnz01-02	8.90	0.291	0.078	188	9.83
Mnz01-03	10.68	0.535	0.090	172	12.41
Mnz01-04	8.90	0.266	0.076	184	9.75
Mnz01-05	8.56	0.283	0.075	188	9.47
Mnz01-06	8.74	0.284	0.074	182	9.65
Mnz01-07	9.11	0.286	0.078	183	10.03
Mnz01-08	10.25	0.337	0.083	174	11.33
Mnz01-09	8.71	0.320	0.077	188	9.75
Mnz01-10	9.33	0.306	0.080	184	10.32
Mnz01-11	9.22	0.288	0.077	180	10.15
Mnz01-12	8.78	0.278	0.075	184	9.68
Mnz01-13	9.84	0.334	0.084	182	10.91
Mnz01-14	10.38	0.347	0.088	180	11.50
Mnz01-15	9.86	0.324	0.083	179	10.90
Mnz01-16	9.16	0.298	0.078	183	10.12
Mnz01-17	9.92	0.377	0.082	174	11.14
Mnz01-18	17.67	0.849	0.153	177	20.41
Mnz01-19	9.39	0.360	0.078	175	10.55
Mnz01-20	9.49	0.367	0.077	171	10.67
Mnz01-21	9.97	0.441	0.090	187	11.40
Mnz01-22	9.87	0.315	0.081	175	10.88
Mnz01-23	21.53	0.889	0.188	182	24.40
Mnz01-24	9.40	0.354	0.082	184	10.54
Mnz01-25	9.73	0.347	0.081	176	10.84
Mnz01-26	10.12	0.328	0.084	177	11.18
Mnz01-27	9.05	0.271	0.076	180	9.92
Mnz01-28	6.65	0.655	0.067	181	8.76
Mnz01-29	8.60	0.734	0.082	177	10.97
Mnz01-30	10.96	0.631	0.099	179	13.00
Mnz01-31	6.64	0.604	0.065	180	8.59
Mnz02-01	10.96	0.376	0.089	172	12.17
Mnz02-02	8.45	0.133	0.068	181	8.88
Mnz02-03	9.25	0.127	0.074	180	9.66
Mnz02-04	5.82	0.056	0.047	186	6.00
Mnz02-05	8.88	0.126	0.068	174	9.29
Mnz02-06	8.45	0.248	0.070	179	9.24
Mnz02-07	9.55	0.736	0.090	179	11.92
Mnz02-08	9.34	0.206	0.076	180	10.01
Mnz02-09	8.62	0.128	0.070	184	9.04
Mnz02-10	9.45	0.178	0.075	177	10.03
Mnz02-11	7.33	0.074	0.058	183	7.57
Mnz02-12	6.41	0.111	0.046	161	6.76
Mnz02-13	9.30	0.198	0.075	179	9.94
Mnz02-14	9.47	0.308	0.080	181	10.46
Mnz02-15	10.16	0.217	0.081	177	10.86
Mnz02-16	8.29	0.162	0.065	175	8.82
Mnz02-17	10.36	0.291	0.089	186	11.30
Mnz02-18	7.92	0.122	0.062	176	8.31
Mnz02-19	9.79	0.315	0.080	176	10.80
Mnz02-20	8.90	0.154	0.069	173	9.40
Mnz02-21	9.61	0.315	0.080	178	10.63
Mnz02-22	8.68	0.254	0.073	182	9.50
Mnz02-23	9.13	0.271	0.073	172	10.01
Mnz02-24	10.09	0.275	0.086	184	10.98
Mnz02-25	9.29	0.268	0.077	179	10.16
Mnz02-26	9.52	0.191	0.079	184	10.13
Mnz02-27	7.71	0.122	0.060	174	8.10
Mnz02-28	12.55	0.115	0.097	178	12.92
Mnz02-29	8.41	0.281	0.070	176	9.32
Mnz02-30	8.97	0.444	0.078	176	10.40
Mnz02-31	11.00	0.325	0.088	172	12.05
Mnz02-32	8.38	0.145	0.068	181	8.85
Mnz02-33	8.09	0.232	0.068	182	8.84
Mnz02-34	11.47	0.446	0.098	180	12.91
Mnz02-35	13.24	0.236	0.104	176	14.00
Mnz02-36	14.57	0.352	0.117	177	15.70
Mnz02-37	13.70	0.193	0.104	172	14.32
Mnz02-38	10.66	0.121	0.081	173	11.05
Mnz02-39	9.75	0.318	0.080	176	10.78
Mnz02-40	8.67	0.262	0.074	184	9.51
Mnz02-41	9.32	0.218	0.073	171	10.02
Mnz02-42	9.15	0.139	0.072	176	9.60
Mnz02-43	8.41	0.121	0.067	179	8.80
Mnz02-44	8.80	0.601	0.081	179	10.74
Mnz02-45	10.58	0.194	0.085	180	11.20
Mnz02-46	7.71	0.090	0.059	173	7.99
Mnz02-47	18.23	0.453	0.149	179	19.69
Mnz02-48	12.96	0.129	0.099	176	13.38
Mnz02-49	15.75	0.273	0.125	177	16.63
Mnz02-50	9.14	0.127	0.071	176	9.55
Mnz02-51	17.11	0.336	0.143	186	18.19
Mnz02-52	12.60	0.201	0.096	171	13.25
Mnz02-53	11.19	0.149	0.088	178	11.67
Mnz02-54	9.17	0.160	0.073	179	9.68
Mnz02-55	9.45	0.154	0.077	182	9.95
Mnz02-56	16.51	0.597	0.135	173	18.43
Mnz02-57	21.28	0.614	0.172	174	23.26
Mnz02-58	12.36	0.190	0.097	177	12.98
Mnz02-59	10.24	0.131	0.075	166	10.66
Mnz02-60	8.26	0.151	0.067	181	8.75
Mnz02-61	9.04	0.137	0.070	175	9.48
Mnz02-62	9.79	0.286	0.079	174	10.72
Mnz02-63	11.60	0.332	0.094	175	12.67
Mnz02-64	9.51	0.125	0.073	174	9.91
Mnz02-65	8.67	0.125	0.069	180	9.08
Mnz02-66	11.27	0.230	0.085	168	12.01
Mnz02-67	8.34	0.135	0.067	179	8.78
Mnz02-68	8.44	0.202	0.064	168	9.09
Mnz02-69	8.72	0.127	0.068	177	9.13
Mnz03-01	8.99	0.337	0.078	184	10.08
Mnz03-02	9.52	0.347	0.081	180	10.64
Mnz03-03	9.59	0.337	0.081	179	10.68
Mnz03-04	9.10	0.325	0.079	183	10.15
Mnz03-05	9.09	0.324	0.077	179	10.14

Table 1. (Continued 1.)

Sample. Grain No.	ThO_2 (wt.%)	UO_2 (wt.%)	PbO (wt.%)	Age# (Ma)	ThO_2* (wt.%)
Mnz03-06	7.32	0.134	0.056	170	7.75
Mnz03-07	9.61	0.296	0.079	177	10.57
Mnz03-08	8.91	0.285	0.076	182	9.83
Mnz03-09	8.58	0.260	0.072	182	9.42
Mnz03-10	9.37	0.305	0.077	176	10.36
ST96101703(2) [Granite clast]					
Mnz01-01	6.37	0.215	0.076	253	7.07
Mnz01-02	7.08	0.228	0.081	245	7.82
Mnz01-03	5.26	0.167	0.059	240	5.81
Mnz01-04	5.47	0.124	0.061	244	5.87
Mnz01-05	5.83	0.160	0.067	249	6.35
Mnz01-06	3.97	0.138	0.046	246	4.42
Mnz01-07	6.00	0.159	0.067	242	6.52
Mnz01-08	6.55	0.180	0.075	249	7.13
Mnz01-09	6.63	0.211	0.076	245	7.32
Mnz02-01	9.38	0.179	0.100	236	9.96
Mnz02-02	8.55	0.121	0.093	246	8.94
Mnz02-03	3.72	0.062	0.039	232	3.92
Mnz02-04	9.16	0.164	0.100	243	9.69
Mnz02-05	5.46	0.052	0.061	255	5.63
Mnz02-06	4.07	0.050	0.042	234	4.23
Mnz02-07	6.00	0.160	0.067	244	6.52
Mnz02-08	3.59	0.098	0.042	252	3.91
Mnz02-09	5.57	0.093	0.061	245	5.87
Mnz02-10	6.66	0.166	0.075	247	7.20
Mnz02-11	4.47	0.060	0.046	233	4.66
Mnz02-12	4.80	0.112	0.050	231	5.16
Mnz02-13	5.18	0.074	0.056	244	5.42
Mnz02-14	4.39	0.103	0.049	246	4.72
Mnz02-15	5.29	0.145	0.061	250	5.76
Mnz02-16	5.65	0.151	0.065	249	6.13
Mnz02-17	3.57	0.094	0.040	243	3.88
Mnz02-18	6.21	0.186	0.070	242	6.82
Mnz02-19	5.10	0.135	0.059	252	5.54
Mnz02-20	5.84	0.187	0.066	243	6.45
Mnz02-21	5.55	0.147	0.062	244	6.03
Mnz03-01	3.32	0.132	0.042	262	3.74
Mnz03-02	2.84	0.107	0.031	232	3.19
Mnz03-03	3.08	0.093	0.036	251	3.38
Mnz03-04	4.09	0.094	0.046	249	4.40
Mnz03-05	6.50	0.204	0.076	251	7.17
Mnz03-06	13.99	0.304	0.156	245	14.98
Mnz03-07	8.61	0.253	0.097	242	9.43
Mnz03-08	8.30	0.278	0.095	244	9.21
Mnz03-09	8.36	0.253	0.094	241	9.18
Mnz03-10	15.92	0.330	0.179	248	16.99
Mnz03-11	11.24	0.268	0.127	248	12.10
Mnz03-12	10.78	0.265	0.118	240	11.64
Mnz03-13	13.83	0.303	0.152	242	14.81
Mnz03-14	9.44	0.251	0.106	244	10.25
Mnz03-15	8.49	0.223	0.091	234	9.21
Mnz03-16	6.56	0.159	0.073	244	7.07
Mnz03-17	3.82	0.076	0.043	247	4.07

Sample Grain No.	ThO_2 (wt.%)	UO_2 (wt.%)	PbO (wt.%)	Age# (Ma)	ThO_2* (wt.%)
Mnz03-18	4.30	0.083	0.048	248	4.57
Mnz03-19	3.91	0.071	0.043	246	4.14
Mnz03-20	2.70	0.078	0.031	250	2.95
Mnz03-21	6.16	0.141	0.070	250	6.62
Mnz03-22	7.11	0.192	0.079	240	7.73
YK91042703F [Granite clast]					
Mnz01-01	6.99	0.215	0.083	255	7.68
Mnz01-02	9.01	0.265	0.109	261	9.87
Mnz01-03	7.28	0.253	0.085	248	8.10
Mnz01-04	6.67	0.187	0.074	240	7.28
Mnz01-05 R	8.20	0.253	0.077	202	9.02
Mnz01-06	7.39	0.272	0.093	266	8.27
Mnz02-01	8.18	0.405	0.105	261	9.49
Mnz02-02	7.21	0.316	0.091	261	8.24
Mnz02-03	7.24	0.275	0.090	261	8.13
Mnz02-04	7.27	0.262	0.090	262	8.12
Mnz03-01	9.08	0.347	0.110	255	10.21
Mnz03-02	9.76	0.398	0.120	257	11.05
Mnz03-03 R	10.90	0.397	0.112	217	12.19
Mnz03-04	8.08	0.269	0.096	253	8.95
Mnz04-01	8.23	0.329	0.099	252	9.30
Mnz04-02	8.24	0.348	0.097	245	9.37
Mnz04-03	8.41	0.345	0.110	273	9.53
Mnz04-04	5.53	0.179	0.066	255	6.11
Mnz04-05	5.65	0.257	0.070	255	6.48
Mnz05-01	8.99	0.282	0.107	255	9.90
Mnz05-02	9.49	0.325	0.116	260	10.54
Mnz05-03	10.19	0.372	0.132	273	11.40
Mnz05-04	9.15	0.267	0.113	266	10.02
Mnz06-01	10.23	0.400	0.121	248	11.53
Mnz06-02	11.84	0.460	0.149	264	13.33
Mnz06-03	8.95	0.334	0.112	264	10.04
Mnz07-01	8.75	0.370	0.109	259	9.95
Mnz07-02	8.49	0.320	0.097	241	9.53
Mnz08-01	8.18	0.377	0.106	266	9.40
Mnz08-02	7.75	0.296	0.088	239	8.71
Mnz09-01	11.88	0.431	0.137	244	13.27
Mnz09-02	8.57	0.328	0.108	265	9.63
Mnz09-03 R	13.20	0.420	0.133	216	14.55
Mnz10-01	9.27	0.321	0.116	266	10.31
Mnz10-02	6.13	0.207	0.076	264	6.80
Mnz10-03	13.62	0.477	0.164	255	15.17
Mnz10-04	15.37	0.498	0.187	260	16.98
Mnz10-05	6.43	0.226	0.075	247	7.17
Mnz11	9.59	0.396	0.121	263	10.88
Mnz12	6.66	0.257	0.085	268	7.50
Mnz13	8.93	0.374	0.111	258	10.14
Mnz14	8.78	0.353	0.111	264	9.92
Mnz15	6.88	0.308	0.087	261	7.88
Mnz16	10.88	0.402	0.133	258	12.18
Mnz17-01	15.23	0.661	0.193	262	17.38
Mnz17-02	16.05	0.740	0.205	262	18.45
Mnz17-03	16.06	0.597	0.193	253	17.99

Table 1. (Continued 2.)

Sample. Grain No.	ThO_2 (wt.%)	UO_2 (wt.%)	PbO (wt.%)	Age# (Ma)	ThO_2* (wt.%)
Mnz17-04	13.1	0.624	0.172	269	15.1
Mnz17-05	15.9	0.732	0.202	261	18.3
Mnz17-06	12.4	0.542	0.156	261	14.1
Mnz18	8.30	0.346	0.099	248	9.42
Mnz19-01	15.2	0.547	0.177	246	17.0
Mnz19-02	14.9	0.560	0.177	250	16.8
Mnz20	10.5	0.438	0.130	258	11.9
Mnz21	7.74	0.325	0.101	271	8.79
Mnz22	12.08	0.469	0.151	262	13.6
Mnz23	7.89	0.314	0.100	265	8.91
Mnz24	9.65	0.420	0.125	268	11.0
Mnz25	6.98	0.266	0.087	262	7.84
M2nz6	6.89	0.319	0.090	268	7.92
Mnz27	7.28	0.288	0.086	247	8.22
Mnz28	7.08	0.280	0.088	260	7.99
Mnz29	8.10	0.318	0.092	238	9.13
Mnz30	7.31	0.324	0.093	263	8.36
KS89081301 [Granite clast]					
Mnz01	7.47	0.109	0.078	236	7.83
Mnz02	15.5	0.125	0.163	241	16.0
Mnz03	13.8	0.339	0.142	225	14.9
Mnz04	12.7	0.319	0.138	237	13.7
Mnz05	15.0	0.239	0.151	226	15.8
					UO_2**
Zrn01	0.253	0.616	0.023	244	0.694
Zrn02	1.075	0.709	0.035	247	1.041
Zrn03	0.578	0.403	0.019	240	0.581
YK91053001C [Granite clast]					**UO_2****
Zrn01	0.555	0.439	0.021	253	0.610
Zrn02	0.764	0.542	0.020	190	0.779
Zrn03-01	1.459	0.589	0.037	262	1.04
Zrn03-02	1.158	0.747	0.038	253	1.10
Zrn03-03	0.936	0.764	0.036	251	1.05
Zrn04	0.301	0.390	0.016	244	0.483
Zrn05	0.208	0.321	0.013	248	0.385
YK91042603I [Granite clast]					**UO_2****
Zrn01	0.111	0.592	0.021	247	0.626

Sample. Grain No.	ThO_2 (wt.%)	UO_2 (wt.%)	PbO (wt.%)	Age# (Ma)	UO_2* (wt.%)
Zrn02	0.111	0.588	0.020	237	0.622
Zrn03	0.080	0.479	0.017	248	0.504
KS89081302 [Sandstone]					
Zrn01	0.009	0.039	0.014	2023	0.041
Zrn02	0.255	0.973	0.026	183	1.05
Zrn03	1.18	0.934	0.042	238	1.30
Zrn04	0.429	0.527	0.023	256	0.659
Zrn05	0.807	0.611	0.022	189	0.861
YK91042601A [Sandstone]					
Zrn01	0.137	0.362	0.018	325	0.404
Zrn02	0.046	0.332	0.016	337	0.346
Zrn03	0.161	0.353	0.025	449	0.402
Zrn04	0.811	0.337	0.028	349	0.585
Zrn05	0.230	0.398	0.023	357	0.468
Zrn06	0.008	0.138	0.041	1803	0.140
Zrn07	0.020	0.164	0.057	2015	0.169
Zrn08-01	1.094	0.728	0.039	269	1.065
Zrn08-02	0.799	0.542	0.027	252	0.788
Zrn09	0.171	0.514	0.019	247	0.567
Zrn10-01	0.205	0.645	0.024	249	0.708
Zrn10-02	0.067	0.357	0.013	253	0.378
Zrn10-03	0.256	0.672	0.026	254	0.751
Zrn10-04	0.203	0.827	0.031	256	0.890
Zrn11	0.266	0.441	0.014	198	0.523
YK91042705D [Sandstone]					
Zrn01-01	0.072	0.137	0.053	2031	0.156
Zrn01-02	0.017	0.190	0.063	1955	0.195

Mnz : monazite
Zrn : zircon
R : rim of grain
: apparent age
* : sum of the measured ThO_2 and ThO_2 equivalent of the measured UO_2
** : sum of the measured UO_2 and UO_2 equivalent of the measured ThO_2

RESULTS

The ThO_2, UO_2 and PbO contents of analyzed monazite and zircon grains, and apparent ages are listed in Table 1.

Granite clasts

[YK91042703F: Phgitani conglomerate]

A total of 64 points on 30 monazite grains were analyzed. The ThO_2 content varies from 5.53 to 16.1 wt.%, UO_2 from 0.179 to 0.740 wt.% and PbO from 0.066 to 0.205 wt.%. Apparent ages are from 202 to 273 Ma. Excluding three data (open circles in Fig. 5-A) define an isochron of 259±7 Ma (MSWD=0.25) (Fig.5-A).

[KS89081301: Ohgitani conglomerate]

A total of 5 points on 5 monazite grains were analyzed. The ThO_2 content varies from 7.47 to 15.5 wt.%, UO_2 from 0.109 to 0.339 wt.% and PbO from 0.078 to 0.163 wt.%. Apparent ages are from 225 to 241 Ma. Analytical data define a tentative isochron of

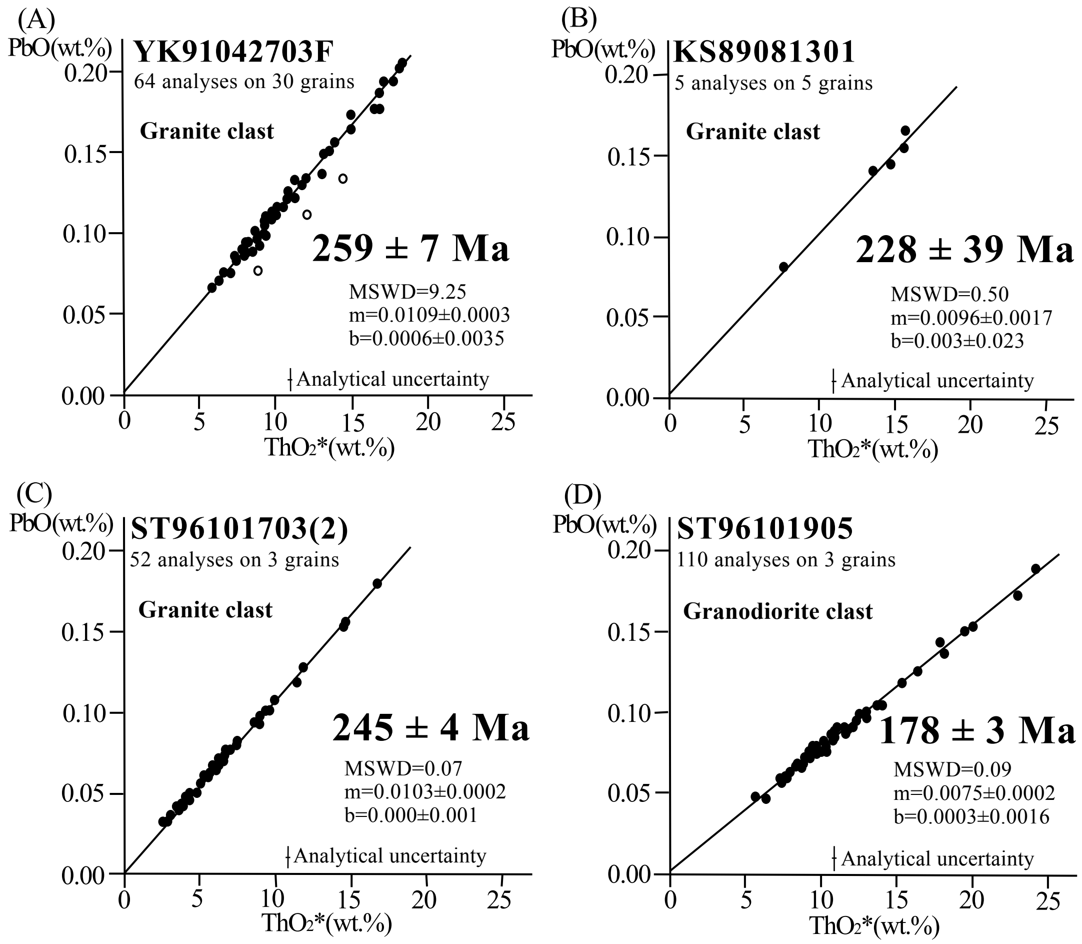

Fig. 5. Plots of PbO vs. ThO_2* for monazite from the granitoid clasts. (A): Sample YK91042703F (granite clast). (B): Sample KS89081301 (granite clast). (C): Sample ST96101703(2) (granite clast). (D): Sample ST96101905 (granitoid clast). Error bars and quoted error are of 2σ. MSWD: Mean Square Weighted Deviates Open circles in (A) show data from grain rim. ThO_2*: measured ThO_2 plus ThO_2 equivalent of the measured UO_2.

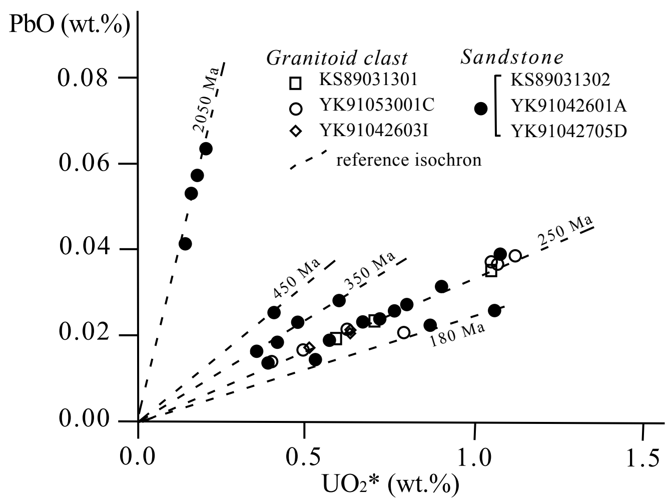

Fig. 6. Plots of PbO vs. UO_2* for zircon from sandstone, and from granite clasts. UO_2*: measured UO_2 plus UO_2 equivalent of the measured ThO_2.

228±39 Ma (MSWD=0.50) (Fig. 5-B).

A total of 3 points on 3 zircon grains were analyzed. The ThO_2 content varies from 0.253 to 1.08 wt.%, UO_2 from 0.403 to 0.709 wt.% and PbO from 0.019 to 0.035 wt.%. Apparent ages are from 240 to 247 Ma (Fig. 6).

[YK91053001C: Ohgitani conglomerate, mylonitized granite]

A total of 7 points on 5 zircon grains were analyzed. The ThO_2 content varies from 0.208 to 1.46 wt.%, UO_2 from 0.321 to 0.764 wt.% and PbO from 0.013 to 0.038 wt.%. Apparent ages are from 190 to 262 Ma. Apparent age cluster around 250 Ma except for a younger age of 190 Ma (Fig. 6).

[YK91042603I: Ohgitani conglomerate]

A total of 3 points on 3 zircon grains were analyzed. The ThO_2 content varies from 0.080 to 0.011 wt.%, UO_2 from 0.479 to 0.592 wt.% and PbO from 0.017 to 0.021 wt.%. Apparent ages are from 237 to 248 Ma (Fig. 6).

[ST96101703(2): Bandokoro conglomerate]

A total of 52 points on 3 monazite grains were analyzed. The ThO_2 content varies from 2.70 to 15.9 wt.%, UO_2 from 0.078 to 0.330 wt.% and PbO from 0.031 to 0.179 wt.%. Apparent ages are from 231 to 255 Ma. Analytical data define an isochron of 245±4 Ma (MSWD=0.07) (Fig. 5-C).

Granodiorite clast

[ST96101905: Tsukiyozawa conglomerate]

A total of 110 points on 3 monazite grains were analyzed. The ThO_2 content varies from 5.82 to 21.5 wt.%, UO_2 from 0.056 to 0.889 wt.% and PbO from 0.046 to 0.118 wt.%. Apparent ages are from 164 to 188 Ma. Analytical data define an isochron of 178±3 Ma (MSWD=0.09) (Fig. 5-D).

Detrital zircon from sandstone

[YK91042601A, YK91042705D, KS89081302: Ohgitani area]

A total of 22 points on 17 detrital zircon grains from three samples were analyzed. Apparent ages are scattered between the ca. 2050 and ca. 180 Ma, with a cluster at ca. 250 Ma (Fig. 6).

DISCUSSION

Detrital zircon from the massive sandstone in the vicinity of the Ohgitani conglomerate and matrix sandstone of the Ohgitani conglomerate yield ages ranging from 2031 to 183 Ma (Fig. 6). Some data points cluster around the 2000 Ma and 250 Ma reference isochrons, and the others between the 450 and 180 Ma reference isochrons. Suzuki et al. (1991) reported apparent ages of monazite from the Jurassic sandstone in the Mino terrane that lie between 1740 and 1420 Ma reference isochrons, and between 274 and 161 Ma reference isochrons, and also cluster around the 1250, 800 and 400Ma reference isochrons. These age data suggest the possibility of several thermal events (ca. 2000, 1740-1420, 1250, 800, 450-350 and 270-160 Ma) in the provenance of Jurassic clastic rocks in Mino terrane.

Monazite and zircon ages of the granite clasts fall between ca. 270 and 190 Ma, with most samples having ages that lie within error of 250 Ma. The granodiorite clast has an isochron age of 178±3 Ma. Since the blocking temperature for Pb in monazite (ca. 700℃; Parrish, 1990; Smith and Barreiro, 1990; Suzuki et al., 1994) is close to the temperature for crystallization of granitic magmas (e.g. Merril et al., 1970; Roberson and Wyllie, 1971), and the clasts show no evidence of subsequent metamorphism, these ages can be interpreted as emplacement time of granitoid masses that were part of the provenance of the Mino terrane. Concentric and oscillatory growth zoning in monazite grains from sample ST96101703(2) (Figs 4-A, B and C) also suggests that the CHIME ages represent the crystallization age of the host granite. In sample YK91042703F, most of the analyzed spots yield apparent ages ranging from 250 to 240 Ma, but three spots yield younger ages of ca. 217, 216 and 202 Ma. These younger apparent ages may be a result of Pb loss after crystallization. The CHIME zircon data of sample KS89081301 show 240 to 247 Ma, which are consistent with its isochronal monazite age of 228±39 Ma within error. The mylonitized granite clast of sample YK91053001C yields apparent ages of ca. 250 Ma and 190 Ma. Probably ca. 250 Ma regarded as emplacement time of the granite, while younger age of ca. 190 Ma may due to Pb loss as a result of mylonitic deformation or heating.

Detrital monazite grains with apparent ages between 1800 and 1000 Ma, especially between 1800 and 1400 Ma (Suzuki et al., 1991) are interpreted as being derived from metamorphic rocks and igneous rocks (e.g. Adachi and Suzuki, 1993; Tanaka et al., 2002).

During the Permo-Triassic, there was igneous and metamorphic activity at the eastern margin of Asian continent. The ca. 250 Ma granites are contemporaneous with thermal events in the Hida terrane (Hida metamorphism: e.g. Ota and Itaya, 1989; the Hida granite: e.g. Kano, 1990; Kunugiza and Kaneko, 2001), and granitoids occurring as clasts from the Usuginu-type conglomerate (Shibata, 1973; Takeuchi and Suzuki, 2000), and the Hirasawa Granitic Mass in the South Kitakami terrane (Suzuki and Adachi, 1993). Ca. 250 Ma granitoids are also reported from the Outer Zone of southwest Japan, including the Kinshozan quartz diorite (e.g. Ono, 1983; Takagi et al., 1989) in the Kanto Mountains, and the Hyokoshi granite in the Akaishi Ranges (Shibata et al., 1993). These Kinshozan quartz diorite and Hyokoshi granite, and granitoid clasts in Usuginu-type conglomerate obviously differ from the analyzed clasts in lithology: analyzed ca. 250 Ma clasts in this study are rich in potassium feldspar, so these are not considered as origin of the ca. 250 Ma granite clasts.

The ca. 180 Ma granodiorite clast has the same age as some of the Hida granites (Kano, 1990) and Funatsu granites (e.g. Shibata and Nozawa, 1984) in the Hida terrane, and the Daebo granites (Lee, 1987) in the Korean Peninsula. Igneous activity in same period has also been reported in southeast China and in the Qinling region of China (Yang et al., 1986). The Funatsu granites in the Noto Peninsula from volcano-plutonic complex (Kanayama et al., 1999). Clasts of acidic to intermediate volcanic, volcano-clastic and hypabyssal rocks in the Jurassic conglomerates of the Mino terrane might be also derived from the Jurassic volcano-plutonic complex.

It is also possible that exhumation around the Qinling-Dabie suture zone between the Sino-Korean and Yangtze blocks, which is characterized by ca. 250 Ma metamorphic rocks provided the Mino terrane with large terrigenous clastics (Isozaki and Maruyama, 1991; Isozaki, 1997). However clasts of ca. 250 Ma metamorphic rocks have not been reported from the Mino terrane. At present, source rocks of Ca. 850 Ma and ca. 450 Ma monazite are still unknown, though these ages are apparent.

CONCLUSION

CHIME ages of granite and mylonitized granite clasts from the Jurassic Ohgitani and Bandokoro conglomerates in the Mino terrane cluster around 250 Ma (Permian to Triassic). One granodiorite clast from the Jurassic Tsukiyozawa conglomerate has a CHIME age of ca. 178 Ma (Early to Middle Jurassic). Results of chronological study can be concluded that the source rocks of the Jurassic clastic rocks of the Mino terrane include granitoids of the Permian to Middle Jurassic as well as Proterozoic metamorphic rocks and igneous rocks.

ACKNOWLEDGEMENTS

We would like to express our thanks to Drs. H. Yoshida and M. Takeuchi of Nagoya University for reading the draft and making a number of helpful discussion. We are also grateful for the constructive criticism from the journal reviewer. We are indebted to Mr. S. Yogo of Nagoya University for his technical assistance in preparing the thin sections for CHIME, and My. T. Kato of Nagoya University for his support to carry out CHIME dating. Thanks are also due to member of Tectonics Group for their encouragement.

REFERENCES

Adachi, M. (1971) Permian intraformational conglomerate at Kamiaso, Gifu Prefecture, central Japan. *J. Geol. Soc. Japan*, **77**, 471-482.

Adachi, M. and Suzuki, K. (1993) Were Precambrian gneiss clasts in the Kamiaso conglomerate derived from the eastern Korean Peninsula? *Bull Nagoya Univ. Furukawa Museum*, No. 9, 25-45.*

Adachi, M. and Suzuki, K. (1994) Precambrian detrital monazites and zircons from Jurassic turbidite sandstones in the Nomugi area, Mino terrane. *J. Earth Planet. Sci. Nagoya Univ.*, **41**, 33-43.

Åmli, R. and Griffin, W.L. (1975) Microprobe analysis of REE minerals using empirical correction factors. *Amer. Mineral.*, **60**, 599-606.

Bence, A.E. and Albee, A.L. (1968) Empirical correction factors for the electron microanalysis of silicates and oxides. *J. Geol.*, **76**, 382-403.

Hattori, I., Hattori, A. and Ueyama, K. (1985) Kanmuriyama Conglomerates - Mesozoic conglomerates in the northwestern Mino Terrane: a comparative study of the Mesozoic conglomerates in the Mino and the Hida Terranes in Fukui Prefecture, central Japan. *Mem. Fac. Educ. Fukui. Univ.*, ser. 2, **35**, 33-47.*

Isozaki, Y. (1997) Jurassic accretion tectonics of Japan. *Island Arc*, **6**, 25-51.

Isozaki, Y. and Maruyama, S. (1991) Studies on orogeny based on plate tectonics in Japan and new geotectonic subdivision of the Japanese Islands. *J. Geogr.*, **100**, 697-761.*

Kanayama, K., Hiroi, Y. and Shibata, K. (1999) Jurassic volcano-plutonic complex in the northwestern part of the Noto Peninsula, Central Japan. *Mem. Geol. Soc. Japan*, No. 53, 299-308.*

Kano, T. (1990) Intrusive relation of the Okumayama Granitic Mass (Shimonomoto type) into the Iori Granitic Mass (Funatsu type) in the Hayatsukigawa area; Re-examination of the subdivision for early Mesozoic granites (Funatsu Granites) in the Hida region. *J. Geol. Soc.*

Japan, **96**, 379-388.*
Kanuma, M. and Irie, K. (1962) On the geology of the Yoro massif, Gifu Prefecture, Japan. *Bull. Tokyo Gakugei Univ.*, **13**, 211-217.*
Kobayashi, Y. (1998) Triassic and Jurassic radiolarian assemblages from the Samondake Unit of the. Mino Terrane in the Neo-Izumi area, central Japan. *J. Fac. Sci., Shinshu Univ.*, **33**, 27-63.*
Kojima, S. (1989) Mesozoic terrane accretion in Northeast China, Sikhote-Alin and Japan regions. *Palaeogeogr. Palaeoclimatol. Palaeoecol.*, **69**, 213-232.
Kunugiza, K. and Kaneko, H. (2001) Metamorphic rocks and granites of the eastern Hida belt, Toyama Prefecture. *Excursion Guidebook The 108th Ann. Meet. Geol. Soc. Japan*. 137-156.***
Lee, D.S. (1987) *Geology of Korea*. GEol. SOc. Korea, Kyohak-Sa Co., Seoul, 514p..
Merril, R.B., Robertson, J.K. and Wyllie, P.J. (1970) Melting reactions in the system $NaAlSi_3O_8$-$KAlSi_3O_8$-SiO_2-H_2O to 20 kilobars compared with results for other fedspar-quartz-H_2O and rock-H_2O systems. *J. Geol.*, **78**, 558-569.
Nakae, S. (2000) Regional correlation of the Jurassic accretionary complex in the Inner Zone of Southwest Japan. *Mem. Geol. Soc. Japan*, No. 55, 73-98.*
Nakano, S., Otsuka, T., Adachi, M., Harayama, S. and Yoshioka, T. (1995) *Geology of the Norikuradake district*. With Geological Sheet Map at 1: 50,000, Geol. Surv. Japan, 139p.*
Okumura, A. and Otsuka, T. (1996) Late Middle Jurassic and early Late Jurassic radiolarian assemblages from the Misogawa complex of the Mino terrane, central Japan. *J. Fac. Sci., Shinshu Univ.*, **31**, 21-42.*
Ono, A. (1983) K-Ar ages of the Kinshozan quartz diorite from the Kanto Mountains. *J. Min. Pet. Econ. Geol.*, **78**, 38-39.*
Ota, K. and Itaya, T. (1989) Radiometric ages of granitic and metamorphic rocks in the Hida metamorphic belt, central Japan. *Bull. Hiruzen Res. Inst., Okayama Univ. of Sci.*, No. 15, 1-25.*
Otsuka, T. (1985) Upper Paleozoic and Mesozoic strata in the northeastern part of the Mino Terrane, Nagano Prefecture, central Japan. *J. Geol. Soc. Japan*, **91**, 583-598.*
Otsuka, T. (1988) Paleozoic-Mesozoic sedimentary complex in the eastern Mino Terrane, central Japan and its Jurassic tectonism. *J. Geosci., Osaka City Univ.*, **31**, 63-122.
Otsuka, T. and Watanabe, K. (1992) Illite crystallinity and low-grade metamorphism of pelitic rocks in the Mino Terrane, central Japan. *Mem. Geol. Soc. Japan*, No. 38, 135-145.*
Parrish, R.R. (1990) U-Pb dating of monazite and its application to geological problems. *Canad. J. Earth Sci.*, **27**, 1431-1450.
Robertson, J.K. and Wyllie, P.J. (1971) Rock-water systems, with special reference to the water-deficient region. *Amer. J. Sci.*, **271**, 252-277.
Shibata, K. (1973) K-Ar ages of the Hikami granite and the Usuginu granitic clasts. *J. Geol. Soc. Japan*, **79**, 705-707.***
Shibata, K. and Adachi, M. (1974) Rb-Sr whole-rock ages of Precambrian metamorphic rocks in the Kamiaso conglomerate from central Japan. *Earth Planet. Sci. Lett.*, **21**, 277-287.
Shibata, K. and Nozawa, T. (1984) Isotopic ages of the Funatsu Granitic Rocks. *J. Min. Petr. Ecom. Geol.*, **79**, 289-298.*
Shibata, K., Takagi, H., Inazaki, T. and Uchiumi, S. (1993) Granitic rocks and their radiometric ages from the Todai Tectonic Zone in the Aokuzure pass area, Akaishi Range. *J. Geol. Soc. Japan*, **99**, 135-144.*
Smellie, J.A.T., Cogger, N. and Herrington, J. (1978) Standards for quantitative microprobe determination of uranium and thorium with additional information on the chemical formulae of davidite and euxenite-polyclase. *Chem. Geol.*, **22**, 1-10.
Smith, H.A. and Barreiro, B. (1990) Monazite U-Pb dating of staurolite grade metamorphism in pelitic schists. *Contrib. mineral. Petrol.*, **105**, 602-615.
Suzuki, K. and Adachi, M. (1991a) Precambrian provenance and Silurian metamorphism of the Tsubonosawa paragneiss in the South Kitakami terrane, Northeast Japan, revealed by the chemical Th-U-total Pb isochron ages of monazite, zircon and xenotime. *Geochem. J.*, **25**, 357-376.

Suzuki, K. and Adachi, M. (1991b) The chemical Th-U-total Pb isochron ages of zircon and monazite from the Gray Granite of the Hida Terrane, Japan. *J. Earth Sci. Nagoya Univ.*, **38**, 11-37.

Suzuki, K. and Adachi, M. (1993) 240 Ma CHIME ages of monazite and zircon from the Hirasawa Granitic Mass in the South Kitakami terrane. *J. Earth Sci. Nagoya Univ.*, **40**, 1-16.

Suzuki, K. and Adachi, M. (1998) Denuation history of the High T/P Ryoke metamorphic belt, southwest Japan: constrains from CHIME monazite ages of gneisses and granitoids. *J. Metamorphic Geol.*, **16**, 23-37.

Suzuki, K., Adachi, M. and Kajizuka, I. (1994) Electron microprobe observations of Pb diffusion in metamorphosed detrital monazites. *Earth Planet. Sci. Lett.*, **128**, 391-405.

Suzuki, K, Adachi, M. Kato, T. and Yogo, S. (1999) CHIME dating method and its application to the analysis of evolution history of orogenic belts. *Chikyukagaku (Geochemistry)*, **33**, 1-22.*

Suzuki, K., Adachi, M. and Tanaka, T. (1991) Middle Precambrian provenance of Jurassic sandstone in the Mino Terrane, central Japan: Th-U-total Pb evidence from an electron microprobe monazite study. *Sediment. Geol.*, **75**, 141-147.

Takagi, H., Shibata, K., Uchiumi, S. and Fujimori, H. (1989) K-Ar ages of granitic rocks in the nirthern marginal area of the Kanto Mountains. *J. Geol. Soc. Japan*, **95**, 369-380.*

Takeuchi, M. and Suzuki, K. (2000) Permian CHIME ages of leucocratic tonalite clasts from Middle Permian Usuginu-type conglomerate in the South Kitakami Terrane, northeastern Japan. *J. Geol. Soc. Japan*, **106**, 812-815.

Tanaka, K., Kobayashi, K. and Kamei, T. (1952) Stratigraphic setting of Sawando conglomerate. *Sci. Repts., Fac. Education, Shinshu Univ.*, **2**, 108-116.*

Tanaka, S., Suzuki, K. and Adachi, M. (2000) Preliminary report on ca. 178 Ma granitic rock clast from the Jurassic conglomerate in the Tsukiyozawa area, Northeastern Mino terrane, central Japan. *Bull. Nagoya Univ. Museum*, No. 16, 33-41.*

Tanaka, S., Suzuki, K. and Adachi, M. (2002) CHIME ages of Mg-rich garnet bearing gneiss clasts from the Jurassic Sawando conglomerate in the northeastern Mino terrane, central Japan.. *J. Earth Planet. Sci. Nagoya Univ.*, **49**, 1-13.

Wakita, K. (1988) Origin of chaotically mixed rock bodies in the Early Jurassic to Early Cretaceous sedimentary complex of the Mino terrane, central Japan. *Bull. Geol. Surv. Japan*, **39**, 675-757.

Wakita, K., Kijima, S. and Tsukada, K. (2001) Middle Mesozoic accretionary complex of the Mino terrane, and Paleozoic to Mesozoic sedimentary rocks of the Hida marginal belt. *ISRGA Field Guide Book for Major GEologic Units of Southwest Japan, GRD/GIGE Miscellaneous Publication*, No. 11, 165-235.

Yamakita, S. and Otoh, S. (2000) Tectonostratigraphic division of accretionary-sedimentary complex of the Tamba-Mino-Ashio Belt and comparison with the Northern and Southern Chichibu Belts. *Struct. Geol.*, No. 44, 5-32.*

Yang, Z., Cheng, Y. and Wang, H. (1986) *The Geology of China*. Clarendon Press, Oxford, 303p.

*: In Japanese with English abstract
**: In Japanese with German abstract
***: In Japanese