

## CHIME ages of xenotime, monazite and zircon from beryllium pegmatites in the Napier Complex, Khmara Bay, Enderby Land, East Antarctica

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**Abstract:** Dating by the chemical Th-U-total Pb isochron method (CHIME) was carried out on xenotime, monazite and zircon from beryllium pegmatites intruded at about 2500 Ma in the ultrahigh-temperature metamorphic Napier Complex. No meaningful results were obtained on zircon from an associated Be-free pegmatite. All analyzed mineral grains are chronologically heterogeneous, and apparent ages range from ~2460 Ma to 550 Ma with conspicuous concentration at 2200, 1700 and 700 Ma. The  $2168 \pm 36$  Ma age for the chronologically homogeneous, non-metamict core of a large xenotime grain dates intense post-emplacement deformation and metamorphism, possibly the granulite-facies event M-2 proposed by E.S. Grew *et al.* (Polar Geosci., 13, 1, 2000) to explain the breakdown of sapphirine and quartz to sillimanite, surinamite, orthopyroxene and/or garnet in the pegmatites and their host rocks. CHIME ages near ~1700 Ma and ~700 Ma could result from incomplete resetting by amphibolite-facies events (M-3, -4) between ~1100 and ~500 Ma. In general, the minerals appeared to have experienced no significant new growth during the later events, so that the effect of these events is expressed in the U-Th-Pb system in the original mineral. Because most of the ages were obtained on non-metamict portions of the analyzed grains, we doubt that metamictization can be the cause of most of the observed chronological heterogeneity. The lack of evidence for the ~2500 Ma emplacement age in the CHIME data could be due to the reliance on total concentrations of Th, U and Pb, which may be more affected by subsequent deformation and metamorphism than the isotope ratios measured in conventional U-Pb dating.

**key words:** pegmatite, beryllium, Antarctica, Archean, CHIME dating, Napier Complex

### 1. Introduction

The Napier Complex has had an extended history of crust formation and tectonothermal activity beginning in the early Archean and extending into the early Paleozoic (*e.g.*, Sheraton *et al.*, 1987; Harley and Black, 1997). Two relatively well-defined events include metamorphism, pegmatite intrusion and deformation at ~2500 Ma and ~500 Ma; the latter is most intense in the exposures along the south coast of Khmara and Casey Bays (Fig. 1; Sandiford, 1985; Harley, 1985). Less well defined in the Napier

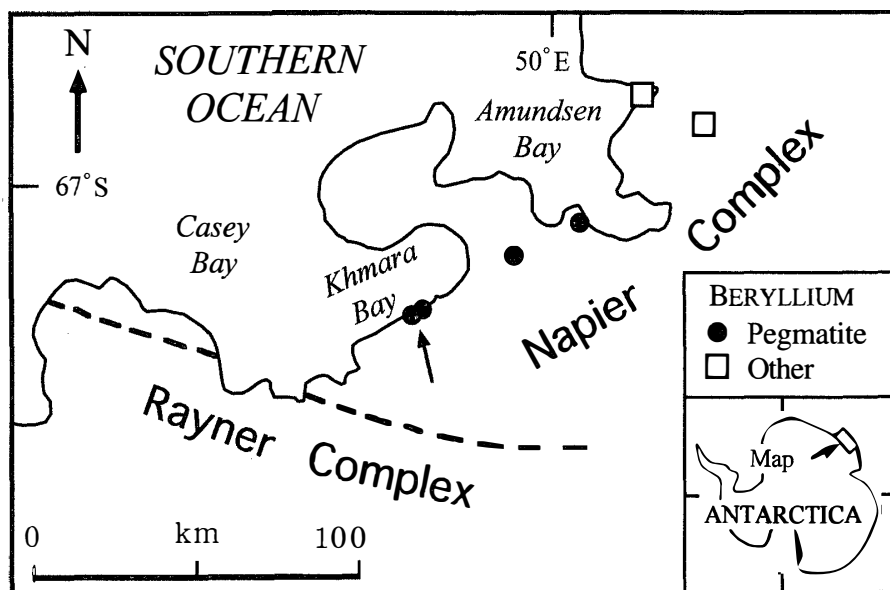


Fig. 1. Map of western Enderby Land showing location of the beryllium pegmatites at "Christmas Point" (arrow) relative to the boundary between the Rayner and Napier Complexes (simplified from Sheraton *et al.*, 1987). "Beryllium" refers to occurrences of Be-rich minerals (Grew *et al.*, 2000).

Complex are events between 2500 and 500 Ma, although the Rayner Complex to the south was affected by a major event at  $\sim 1000$  Ma. Comparable ages in the Khmara Bay area include lead loss ages of 1000 to 1100 Ma (Black *et al.*, 1983, 1984; Grew, 1998) and a chemical Th-U-total Pb isochron method age of  $1094 \pm 67$  Ma on monazite in pegmatite from "Zircon Point" (Asami *et al.*, in review). Because the undeformed and unmetamorphosed Amundsen Dykes that intrude the Napier Complex are older ( $1190 \pm 200$  Ma, Sheraton and Black, 1981; Sheraton *et al.*, 1987), it appears unlikely that the effect of the 1000–1100 Ma event extended beyond the Khmara Bay area and other areas near the boundary between the Napier and Rayner Complexes.

We selected for chemical Th-U-total Pb isochron method (CHIME) dating three samples (Table 1) containing xenotime, monazite, and zircon collected from two beryllium pegmatites (Grew *et al.*, 2000) at "Christmas Point" on JARE-40. Zircon grains in a fourth sample (no. 12234, a pegmatite lacking Be minerals) were analyzed, but they contain too little U and Pb to give meaningful results (Appendix). The polymetamorphic rocks at this locality, which is the southern extremity of one of the Field Islands in Khmara Bay, were affected by ultrahigh-temperature metamorphism in the late Archean and subsequently by amphibolite-facies events, most likely, between  $\sim 1100$  and  $\sim 500$  Ma. The beryllium pegmatites at "Christmas Point" are presumed to be 2500 Ma in age. Upper intercepts with concordia gave 2500 Ma ages for zircons from pegmatites of the same generation at a nearby locality on "Christmas Point" (Black *et al.*, 1983) and on "Zircon Point" and McIntyre Island (Grew *et al.*, 1982; Grew 1998). Our objective was to obtain more evidence for the 1000–1100 Ma event and, if possible, more data that could clarify unresolved questions in the complex metamorphic and deformational history of "Christmas Point".

## 2. Description of the analyzed samples

Sample no. 12212 (Table 1) consists largely of gray medium-grained quartz, red coarse-grained microcline-perthite, yellow-brown apatite, and brown sillimanite, the last in chatoyant prisms up to 5 cm by 4 cm. Subordinate constituents include olive-colored biotite replacing microcline, as well as fine-grained sapphirine (to 0.07 mm long) and rare kyanite (prisms to 1.2 mm long) enclosed in microcline. Fine-grained prismatic sillimanite is aggregated with quartz in microcline. Apatite forms medium-grained aggregates that enclose monazite, wagnerite and coarse-grained xenotime (to 6 mm long); nonetheless xenotime is locally in contact with quartz and microcline (Fig. 2A). The coarse-grained xenotime is optically zoned: a brown core is surrounded by a paler margin of variable thickness.

Wagnerite is more abundant in sample no. 12213, and, together with apatite, is a major constituent of the matrix. Xenotime (to 0.5 mm across) is most commonly surrounded by apatite and wagnerite; contacts with quartz and biotite are few (Fig. 2B, C and D). Microcline forms medium-grained aggregates. Biotite is dark-brown; its aggregates do not appear to be replacing microcline.

In contrast to most samples of the beryllium pegmatites, plagioclase is the dominant feldspar in sample no. 12268, which consists largely of gray quartz, gray and yellowish coarse-grained plagioclase (to 3 cm across), subordinate red microcline (to 6 cm across)

Table 1. Minerals in the studied samples.

Sample Number	12212	12213	12268
Pegmatite number <sup>1</sup>	1	1	2
Quartz	X	X	X
Microcline (Mc)	X	X	T
Plagioclase	–	–	X
Cordierite	–	T	–
Sillimanite	X	X	X
Kyanite	T	–	T
Garnet	–	–	X
Sapphirine (Spr)	–	–	T
Spr in Mc	T	–	–
Zircon	–	T	T
Biotite	X	X	X
Chlorite	–	–	T
Pyrite	–	T	–
Unid. opaque	T	–	T
Rutile	–	T	X
Hematite	–	(?)	–
Ilmenite	–	(?)	–
Spinel	–	–	T
Apatite	X	X	T
Wagnerite	T	X	–
Monazite	T	–	T
Xenotime	X	T	–

Note: Sample numbers are prefixed EG990-. X–major constituent; T–trace constituent.

<sup>1</sup>Pegmatite numbers refer to Grew *et al.* (2000, Table 1).

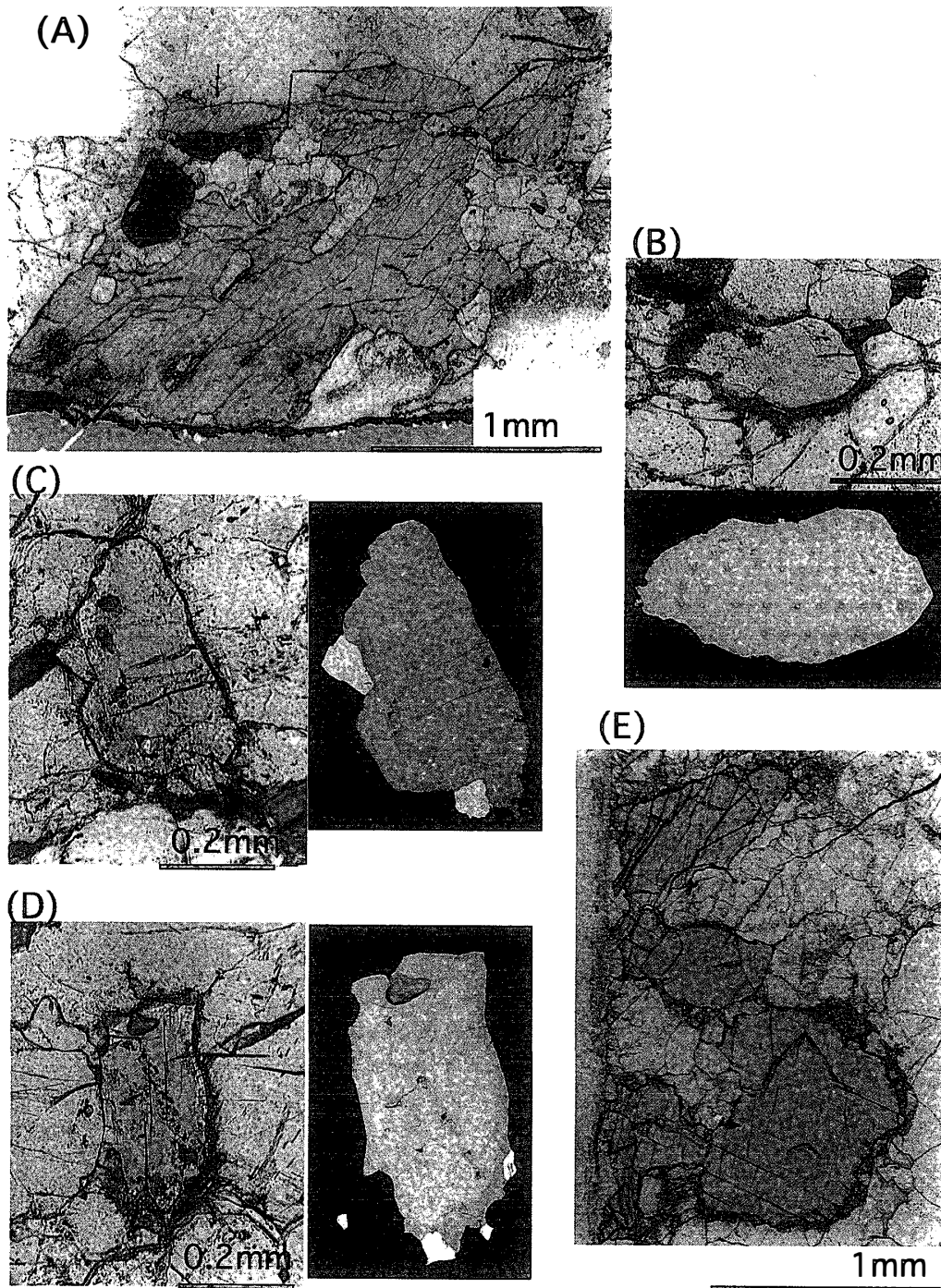


Fig. 2. (A) Photomicrograph in transmitted light of a large xenotime grain in sample 12212. The illustrated portion of the xenotime grain is surrounded largely by microcline and plagioclase with a subordinate amount of quartz. Metamict portions are damaged significantly by the electron beam bombardment (dark spots). (B) Photomicrograph in transmitted light and scanning electron microscope image of X07 xenotime grain surrounded by apatite and wagnerite in sample 12213. This grain was little injured by the electron beam bombardment, and appears to be free from intense metamictization. (C) and (D) Photomicrographs in transmitted light and back-scattered electron images (BSE) of X09 and X10 xenotime grains with distinct Th-poor margins surrounded by apatite and wagnerite in sample 12213. The bright grains next to xenotime in the BSE images are monazite. (E) Photomicrograph in transmitted light of monazite grains (M01-M05) in sample 12268. Lower grains are free from intense metamictization, whereas parts of the upper grains are metamict.

and garnet-biotite aggregates. Plagioclase is locally antiperthitic; its grains are commonly bent and granulated. In the portion of the sample sectioned, fine-grained microcline occurs sparingly at the margins of the coarse plagioclase grains. Brown biotite, together with rare kyanite and sillimanite, appears to be replacing garnet. Sillimanite is more common as prisms to 1 mm across in patches of medium-grained plagioclase formed by granulation of the coarse plagioclase. Apatite occurs sparingly. Monazite occurs as tiny grains at the margin of a plagioclase grain, and a coarse-grained monazite is found in an aggregate of relatively fine-grained microcline, plagioclase and quartz (Fig. 2E).

All three samples show ample evidence for at least two metamorphic events following original crystallization of the pegmatite. Grew *et al.* (2000) inferred that wagnerite, coarse-grained chatoyant sillimanite and a K-feldspar, which subsequently inverted to perthitic microcline, were pegmatitic phases; sapphirine was also an original phase that was preserved as inclusions in microcline. Medium-grained prismatic sillimanite, kyanite, surinamite, garnet and biotite in the analyzed samples are later phases that formed during a superimposed granulite-facies event M-2 and two later amphibolite-facies events (M-3, -4). Textures suggest that xenotime, monazite and zircon are also pegmatitic minerals; whereas the apatite margins around xenotime might be later. An important difference between no. 12212 and no. 12213 is that xenotime is much finer-grained in the latter sample, which could have made the U-Th-Pb system in xenotime more vulnerable to resetting.

### 3. CHIME data

#### 3.1. Methods

Monazite, zircon, and xenotime were analyzed in polished thin sections with a JEOL JXA-733 microprobe analyzer equipped with four wavelength-dispersive spectrometers. Instrument operating conditions were 15 kV accelerating voltage, 0.3  $\mu$ A beam current and 5  $\mu$ m beam diameter. The  $\text{ThM}_{\alpha}$ ,  $\text{UM}_{\beta}$ ,  $\text{PbM}_{\alpha}$  and  $\text{YL}_{\gamma}$  lines were simultaneously measured with the PET crystal for analysis of monazite and zircon. The  $\text{YL}_{\gamma}$  interference of  $\text{PbM}_{\alpha}$  becomes severe for xenotime, and thus the  $\text{PbM}_{\beta}$  line was used instead. X-ray intensity was integrated over a 200-s period for the line-peak position and a 100-s period for two optimum positions on both sides of each line-peak. For the zircon analysis, X-ray intensity was integrated over a 300-s period. The measurement was repeated twice, and the arithmetic average was taken as the true intensity. The detection limit of PbO at the  $2\sigma$  confidence level is 0.01–0.006 wt% for monazite and xenotime and 0.003 wt% for zircon, and the relative error in the PbO determination is 5–10% at the 0.1 wt% concentration level and is much better for the higher concentrations. The X-ray intensity data were converted into concentrations by the Bence and Albee (1968) method. The small difference in the matrix between the reference materials and the samples has little effect on the  $\text{ThO}_2$ ,  $\text{UO}_2$  and PbO determinations; the maximum error in this calculation, about 0.5% of the concentration, is less than the uncertainty in the X-ray counting. Further details on the standards, analytical method, and age calculation method are given by Asami *et al.* (1998, in review) and references cited therein.

### 3.2. Results

A total of 197 spots were analyzed on a relatively coarse-grained xenotime (X1) in sample 12212 (Fig. 2A). Data can be resolved into three major age groupings for which the following CHIME ages were calculated (Fig. 3; Appendix):

- (1)  $2154 \pm 53$  Ma (52 data with apparent ages of  $>2100$  Ma, MSWD=0.18) on a chronologically homogeneous, non-metamict center (inclination:  $0.3671 \pm 0.0119$ , intercept value:  $-0.0134 \pm 0.0365$ ; maximum error in  $\text{UO}_2^* = \pm 0.125$ , error in  $\text{PbO} = \pm 0.045$ ).
- (2)  $1640 \pm 52$  Ma (50 data with apparent ages of 1600–1450 Ma, MSWD=0.84) on a chronologically homogeneous and non-metamict margin (inclination:  $0.2602 \pm 0.0101$ , intercept value:  $-0.0397 \pm 0.0212$ ; maximum error in  $\text{UO}_2^* = \pm 0.088$ , error in  $\text{PbO} = \pm 0.022$ ).

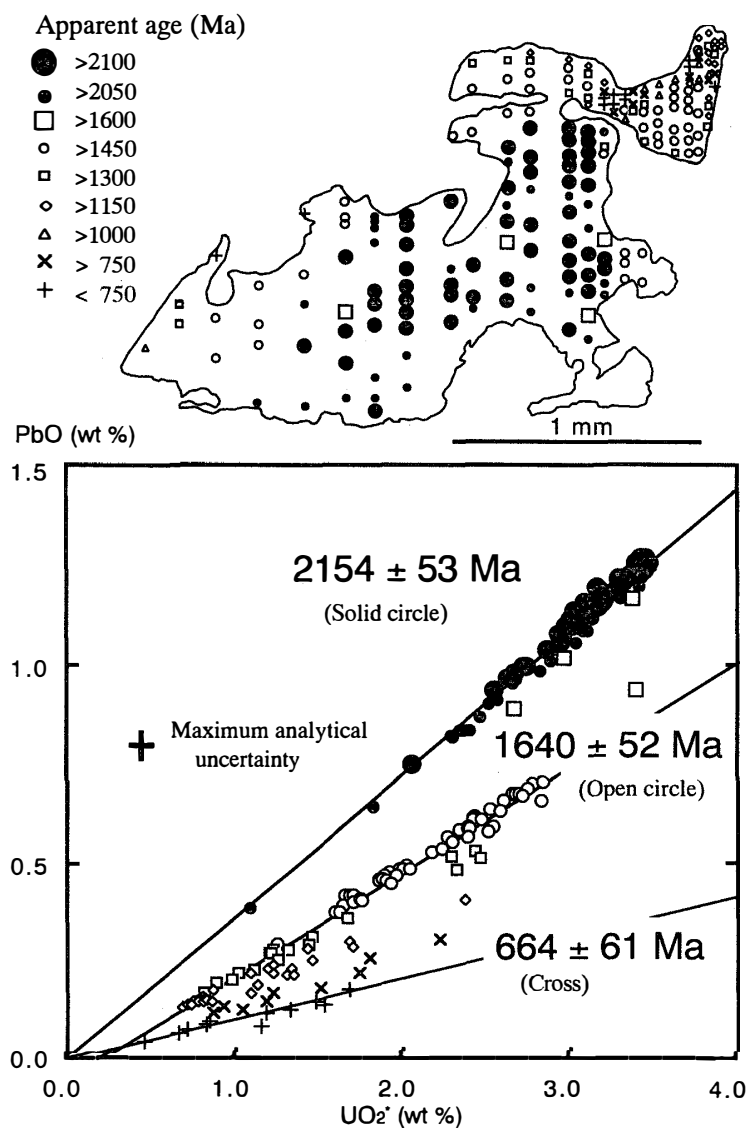


Fig. 3. Sketch of X01 xenotime grain from sample 12212 showing zoning in apparent age, with  $\text{UO}_2^*$ -PbO plot. The error given to the ages is of  $2\sigma$ .

(3)  $664 \pm 61$  Ma (MSWD=0.82) on marginal portions (inclination:  $0.0941 \pm 0.0093$ , intercept value:  $-0.0018 \pm 0.0100$ ; maximum error in  $\text{UO}_2^* = \pm 0.064$ , error in  $\text{PbO} = \pm 0.014$ ).

Ten grains of xenotime were analyzed in sample no. 12213 (Fig. 4). The homogeneous center of non-metamict X07 grain gave a CHIME age of  $1796 \pm 114$  Ma (36 spots with apparent ages older than 1600 Ma, MSWD=2.71, inclination= $0.2912 \pm 0.0230$ , intercept value= $-0.0545 \pm 0.0854$ , maximum error in  $\text{UO}_2^* = \pm 0.127$ , error in  $\text{PbO} = \pm 0.042$ ). Compatible ages were obtained from a small grain (X05) included in quartz (1694–1728 Ma apparent ages) and chronologically homogeneous cores of the relatively large X09 ( $1815 \pm 58$  Ma, 46 analytical data) and X10 ( $1775 \pm 66$  Ma, 52 analytical data) grains. The regression of 134 analyses with apparent ages older than 1600 Ma on centers of large X07, X09 and X10 grains yields a  $1819 \pm 48$  Ma age. The

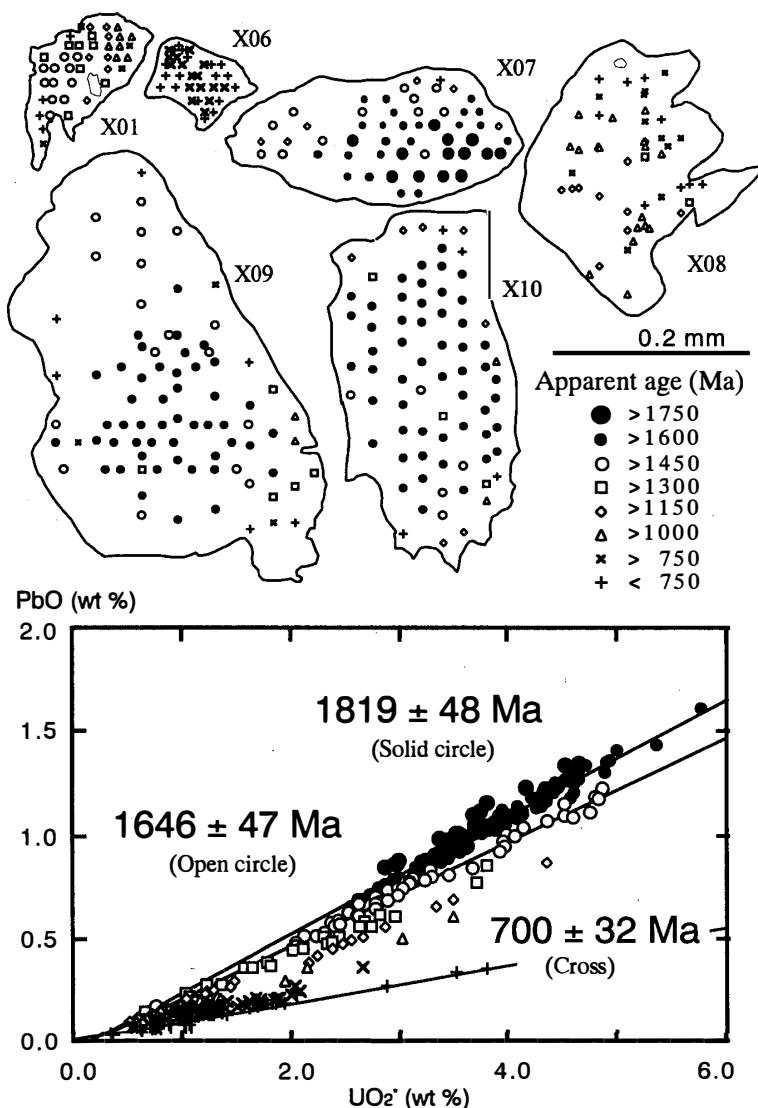


Fig. 4. Sketch of X01, X06, X07, X08, X09 and X10 xenotime grains from sample 12213 showing zoning in apparent age, with  $\text{UO}_2^*$ - $\text{PbO}$  plot. The error given to the ages is of  $2\sigma$ .

homogeneous margins of large grains and the homogeneous centers of small grains (open circle in Fig. 3) give an age of  $1646 \pm 47$  Ma (47 data points, MSWD=2.38, inclination= $0.2616 \pm 0.0090$ , intercept value= $-0.0646 \pm 0.0266$ , maximum error in  $UO_2^* = \pm 0.111$ , error in PbO= $\pm 0.031$ ). Small xenotime grains have much younger apparent ages throughout the grains; a total of 34 data on X06 grain yield an isochron of  $771 \pm 53$  Ma (MSWD=1.39; inclination= $0.1104 \pm 0.0083$ , intercept value= $-0.0061 \pm 0.0104$ ; maximum error in  $UO_2^* = \pm 0.062$ , error in PbO= $\pm 0.015$ ). Fifty-two analyses with apparent ages younger than 750 Ma on the margins of all 10 grains gave  $700 \pm 32$  Ma (MSWD=1.68; inclination= $0.0995 \pm 0.0049$ , intercept value= $0.0018 \pm 0.0066$ ; maximum error in  $UO_2^* = \pm 0.070$ , error in PbO= $\pm 0.015$ ).

Monazite grains in sample 12268 are chronologically heterogeneous (Fig. 5); apparent ages range from 1860 to 560 Ma with exceptionally younger ages (280–500 Ma) for Th-rich metamict portions. A total of 52 spots were analyzed on 2 zircon grains. Two spots show apparent ages of 2440 and 2460 Ma, and the rest are in the range from 2300–1850 Ma. Regression of the 2300–1850 Ma data points yields a CHIME ages of

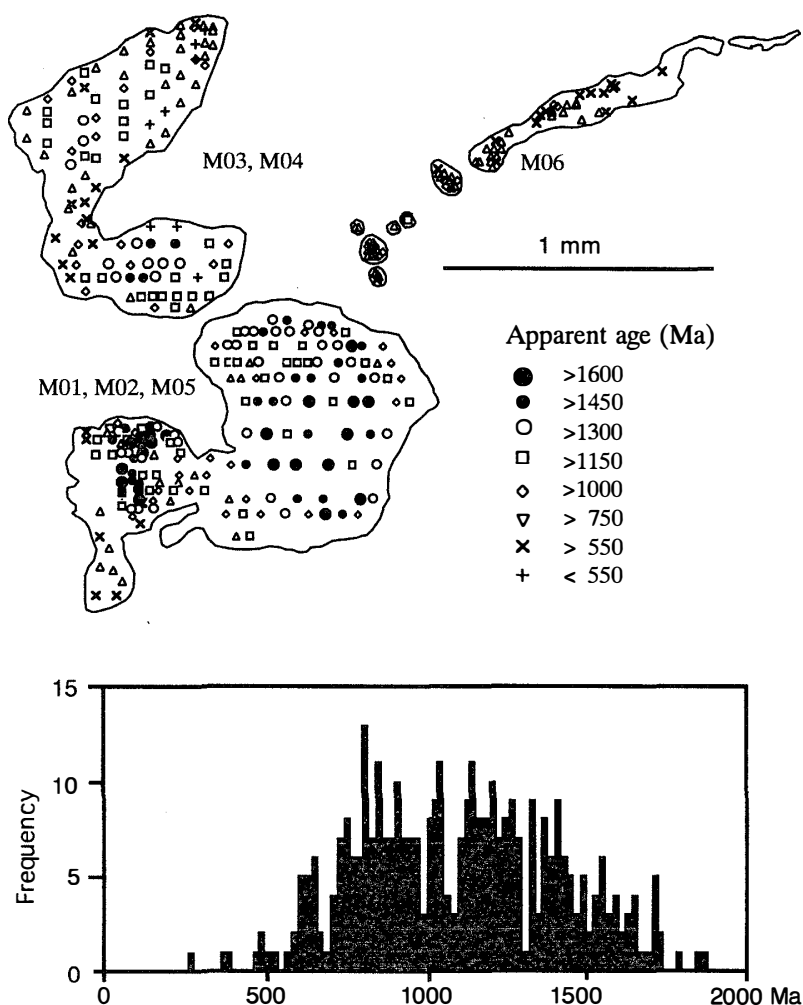


Fig. 5. Sketch of monazite grains from sample 12268 showing zoning in apparent age, with a histogram of apparent ages.



2222 $\pm$ 55 Ma (MSWD=0.23; inclination=0.3829 $\pm$ 0.0126, intercept value=-0.0013 $\pm$ 0.0011; maximum error in UO<sub>2</sub><sup>\*</sup>= $\pm$ 0.029, error in PbO= $\pm$ 0.011).

In summary, the CHIME data record events at the following times: ~2200 Ma (xenotime core, zircon); ~1700 Ma (more xenotime), and ~700 Ma (more xenotime). However, there are many apparent ages in the range 600–1800 Ma for xenotime, and CHIME ages were calculated for what appeared to be concentrations of apparent ages.

#### 4. Discussion

The new CHIME data are only in partial agreement with previously reported geochronologic data for Khmara Bay and elsewhere in the Napier Complex. Events at 2500, 1000–1100 Ma (“Rayner”) and 500 Ma are not apparent in the new CHIME data.

There is no evidence in our CHIME data for events older than 2300 Ma, which is consistent with xenotime, monazite and zircon crystallizing from a pegmatitic melt at 2500 Ma and not being entrained restite from country rock that is significantly older.

However, the CHIME ages of about 2200 Ma are considerably younger than the 2400–2440 Ma CHIME ages on metamorphic monazite and zircon presumed to date the ultrahigh-temperature event (Asami *et al.*, 1998, in review). A simple explanation may be that the beryllium pegmatites were intruded after the ultrahigh-temperature event. However, this is unlikely, because the beryllium pegmatites have the same structural and mineralogical features as pegmatites at nearby localities in the Khmara Bay area dated at ~2500 Ma by U-Pb ages on zircons (Black *et al.*, 1983, 1984; Grew *et al.*, 1982; Grew, 1998). For example, the beryllium pegmatites have the same distinctive coarse sillimanite prisms as “an ‘old’ folded sillimanite pegmatite” on “Christmas Point” dated at 2456 Ma by Black *et al.* (1983, p. 285). In addition, no investigator has reported emplacement of high-temperature pegmatites after the emplacement of undeformed mafic dikes at ~2350–2400 Ma (Sheraton and Black, 1981; Sheraton *et al.*, 1987).

Another explanation more in accord with field relationships is that intense post-emplacement deformation and metamorphism at “Christmas Point” disrupted completely the U-Th-Pb system analyzed by the CHIME. The chronologically uniform core of large X01 xenotime grain in sample 12212 might have been rejuvenated during that event. That is, the 2168 $\pm$ 36 Ma CHIME age for the core dates post-emplacement deformation and metamorphism, possibly the granulite-facies event (M-2) proposed by Grew *et al.* (2000) to explain the breakdown of sapphirine and quartz to sillimanite, surinamite, orthopyroxene and/or garnet in the pegmatites and their host rocks. An age near 2200 Ma is more plausible for this event than an age near 1100 Ma. Asami *et al.* (in review) suggested the latter as a distant possibility although they realized the difficulty posed by the 1190 $\pm$ 200 Ma age for unmetamorphosed and undeformed Amundsen Dykes from several localities in the Napier Complex (Sheraton and Black, 1981; Sheraton *et al.*, 1987). The M-2 overprint was more intense at “Christmas Point” than at “Zircon Point” and the other localities studied by Asami *et al.* (1998, in review), and it is unlikely that the U-Th-Pb system in their samples was seriously disrupted by events after 2400 Ma except in a orthopyroxene quartzofeldspathic granulite from Mt. Riiser-Larsen. Citing a conspicuous concentration of apparent ages at about 2200 Ma in chronologically

heterogeneous monazite grains from this granulite, Asami *et al.* (1998, in review) suggested that Mt. Riiser-Larsen might have been affected by high-temperature activity at ~2200 Ma.

The apparent ages younger than 2000 Ma suggest that several other events also affected the beryllium pegmatites at “Christmas Point”; these could correspond to the amphibolite-facies events M-3 and M-4 of Grew *et al.* (2000). Previous studies suggest ages between ~1100 (Rayner) and ~500 Ma for these events (Black *et al.*, 1983; Harley, 1985; Sandiford, 1985; Sheraton *et al.*, 1987). CHIME ages near ~1700 Ma and less than 750 Ma could result from incomplete resetting of the U-Th-Pb system during events between ~1100 and ~500 Ma, which were in the amphibolite facies and perhaps not hot enough to completely reset the ages in the relatively refractory mineral xenotime. It does not appear likely that the ~1700 age dates a specific event as previous studies have provided no evidence for an event at this time. We note that the absence of a clearcut imprint from the Rayner event could be due to the weakness of this event at “Christmas Point” and its being largely obliterated by the ~500 Ma event, explanations Black *et al.* (1983) cited for its absence in zircon data in a gneiss from “Christmas Point”.

In conclusion, chronological heterogeneity most likely resulted from partial resetting of the U-Th-Pb system in the original minerals during tectonothermal events following intrusion of the pegmatites. Because most of the ages were obtained on non-metamict portions of the analyzed grains, we do not think metamictization played an important role in resetting the U-Th-Pb system in the analyzed grains. This resetting could have affected smaller grains more than larger grains, resulting in the different ages obtained for coarse-grained xenotime in no. 12212 and fine-grained xenotime in no. 12213. Apparently the minerals experienced no significant new growth during the later events, so that the effect of these events is expressed in the U-Th-Pb system in the original mineral. The lack of evidence for the emplacement age in the CHIME data could be due to the reliance on total concentrations of the measured elements for dating. Isotope ratios measured in conventional U-Pb dating of zircon and monazite (*e.g.*, Black *et al.*, 1983, 1984; Grew *et al.*, 1982) could be more robust than total U, Th, and Pb contents of xenotime and monazite analyzed by CHIME, and thus less affected by subsequent deformation and metamorphism.

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Appendix. Microprobe ThO<sub>2</sub>, UO<sub>2</sub> and PbO analyses, apparent ages and ThO<sub>2</sub>\* or UO<sub>2</sub>\* values of xenotime (X), monazite (M) and zircon (Z) in pegmatites from "Christmas Point".

Spot No.	ThO <sub>2</sub> (wt %)	UO <sub>2</sub> (wt %)	PbO (wt %)	Age (Ma)	UO <sub>2</sub> * ThO <sub>2</sub> *	Spot No.	ThO <sub>2</sub> (wt %)	UO <sub>2</sub> (wt %)	PbO (wt %)	Age (Ma)	UO <sub>2</sub> * ThO <sub>2</sub> *
Xenotime											
Sample EG99012212						X01,0485-2438	0.006	1.54	0.132	609	1.54
X01,0092-2219	0.007	0.780	0.147	1244	0.782	X01,0485-2457	0.012	1.69	0.170	705	1.69
X01,0092-2240	0.009	0.750	0.139	1223	0.752	X01,0485-2503	0.059	2.22	0.532	1520	2.24
X01,0118-2219	0.006	0.820	0.148	1195	0.821	X01,0485-2536	0.099	2.36	0.401	1128	2.38
X01,0118-2244	0.007	0.809	0.155	1261	0.811	X01,0525-2433	0.011	1.15	0.0758	471	1.16
X01,0118-2271	0.008	0.821	0.164	1309	0.823	X01,0525-2473	0.006	1.48	0.139	661	1.48
X01,0118-2307	0.072	0.844	0.169	1286	0.865	X01,0525-2507	0.022	1.80	0.252	954	1.81
X01,0118-2350	0.006	0.865	0.112	887	0.867	X01,0567-2380	0.007	0.753	0.142	1241	0.755
X01,0118-2399	0.008	0.852	0.0898	737	0.854	X01,0567-2423	0.011	1.04	0.118	791	1.04
X01,0143-2188	0.011	0.805	0.141	1166	0.808	X01,0567-2449	0.009	1.19	0.113	665	1.19
X01,0143-2239	0.006	0.982	0.196	1311	0.983	X01,0567-2473	0.006	1.33	0.119	631	1.33
X01,0143-2265	0.019	1.10	0.214	1278	1.10	X01,0567-2587	0.197	3.38	1.19	2056	3.43
X01,0143-2303	0.019	1.19	0.228	1261	1.20	X01,0567-2647	0.170	1.41	0.309	1378	1.46
X01,0143-2349	0.019	1.13	0.183	1085	1.14	X01,0567-2675	0.125	2.63	0.671	1595	2.66
X01,0143-2376	0.010	1.19	0.141	818	1.19	X01,0567-3026	0.201	3.36	0.931	1702	3.41
X01,0143-2449	0.014	1.22	0.214	1164	1.23	X01,0567-3108	0.172	3.14	1.18	2173	3.19
X01,0143-2484	0.016	1.21	0.265	1414	1.21	X01,0567-3144	0.174	3.13	1.19	2191	3.17
X01,0143-2519	0.018	1.22	0.234	1261	1.23	X01,0567-3202	0.161	3.05	1.08	2076	3.09
X01,0143-2566	0.023	1.22	0.273	1435	1.23	X01,0567-3248	0.130	2.87	1.00	2054	2.90
X01,0181-2202	0.012	0.686	0.130	1248	0.689	X01,0482-3084	0.113	2.37	0.586	1553	2.40
X01,0181-2259	0.010	0.831	0.144	1151	0.834	X01,0482-3128	0.126	2.45	0.607	1556	2.48
X01,0181-2283	0.007	0.925	0.126	929	0.927	X01,0482-3190	0.142	2.52	0.587	1477	2.55
X01,0181-2312	0.009	1.10	0.162	1000	1.10	X01,0413-3086	0.039	1.92	0.442	1472	1.93
X01,0181-2368	0.012	1.34	0.226	1130	1.34	X01,0413-3203	0.120	2.40	0.610	1591	2.43
X01,0181-2409	0.021	1.59	0.372	1492	1.60	X01,0630-2316	0.006	0.777	0.142	1214	0.778
X01,0181-2459	0.027	1.64	0.387	1503	1.65	X01,0630-2352	0.016	1.21	0.265	1407	1.22
X01,0181-2514	0.020	1.66	0.412	1574	1.66	X01,0630-2399	0.019	1.87	0.456	1549	1.88
X01,0181-2607	0.030	1.68	0.412	1549	1.69	X01,0630-2446	0.015	1.68	0.355	1375	1.68
X01,0181-2669	0.018	1.75	0.399	1463	1.76	X01,0630-2472	0.016	1.69	0.293	1159	1.69
X01,0223-2295	0.012	0.716	0.0671	658	0.720	X01,0630-2584	0.190	3.37	1.22	2106	3.42
X01,0223-2324	0.015	0.830	0.0805	680	0.834	X01,0630-2623	0.197	3.36	1.25	2150	3.41
X01,0223-2364	0.020	1.22	0.161	901	1.23	X01,0630-2673	0.203	3.39	1.26	2149	3.44
X01,0223-2388	0.013	1.42	0.277	1278	1.43	X01,0630-2727	0.204	3.42	1.26	2132	3.47
X01,0223-2423	0.010	1.71	0.412	1535	1.71	X01,0630-2804	0.200	3.41	1.26	2143	3.46
X01,0223-2464	0.021	1.86	0.456	1558	1.86	X01,0630-2885	0.205	3.40	1.22	2094	3.45
X01,0223-2501	0.018	1.88	0.465	1567	1.89	X01,0630-2980	0.215	3.45	1.24	2092	3.50
X01,0223-2575	0.024	1.86	0.457	1562	1.86	X01,0630-3087	0.186	3.17	1.16	2124	3.22
X01,0223-2628	0.029	1.86	0.454	1551	1.86	X01,0630-3171	0.173	3.11	1.15	2148	3.15
X01,0223-2678	0.036	1.91	0.475	1570	1.92	X01,0630-3235	0.151	2.96	1.09	2136	2.99
X01,0282-2372	0.010	1.31	0.210	1079	1.31	X01,0630-3333	0.137	2.95	1.01	2019	2.98
X01,0282-2411	0.014	1.63	0.371	1461	1.63	X01,0630-3438	0.115	2.64	0.948	2097	2.67
X01,0282-2446	0.013	1.74	0.403	1483	1.75	X01,0710-2292	0.009	0.715	0.132	1218	0.717
X01,0282-2490	0.055	2.26	0.563	1573	2.27	X01,0710-2331	0.006	1.25	0.289	1479	1.25
X01,0282-2577	0.048	1.99	0.481	1532	2.01	X01,0710-2373	0.034	2.02	0.489	1539	2.03
X01,0282-2626	0.043	1.98	0.480	1539	1.99	X01,0710-2428	0.077	2.43	0.524	1392	2.45
X01,0282-2672	0.031	1.43	0.287	1309	1.44	X01,0710-2575	0.195	3.37	1.23	2120	3.42
X01,0343-2388	0.006	1.35	0.208	1040	1.35	X01,0710-2618	0.197	3.37	1.23	2122	3.43
X01,0343-2434	0.020	1.70	0.281	1105	1.71	X01,0710-2683	0.191	3.30	1.20	2121	3.34
X01,0343-2502	0.078	2.42	0.615	1594	2.44	X01,0710-2726	0.185	3.25	1.20	2139	3.30
X01,0343-2552	0.083	2.41	0.606	1582	2.43	X01,0710-2788	0.193	3.34	1.22	2121	3.39
X01,0343-2606	0.089	2.37	0.588	1562	2.39	X01,0710-2847	0.208	3.46	1.25	2099	3.51
X01,0343-2641	0.082	2.31	0.579	1574	2.34	X01,0710-2914	0.201	3.42	1.24	2115	3.47
X01,0406-2409	0.007	1.46	0.246	1130	1.46	X01,0710-3034	0.197	3.40	1.23	2107	3.46
X01,0406-2436	0.018	1.75	0.213	842	1.75	X01,0710-3113	0.182	3.25	1.18	2113	3.29
X01,0406-2473	0.046	2.29	0.513	1440	2.30	X01,0710-3180	0.176	3.13	1.14	2115	3.18
X01,0406-2508	0.135	2.74	0.694	1583	2.78	X01,0710-3243	0.154	3.08	1.08	2060	3.12
X01,0406-2575	0.114	2.49	0.633	1589	2.53	X01,0710-3393	0.107	2.53	0.929	2136	2.56
X01,0406-2623	0.094	2.30	0.478	1340	2.33	X01,0863-2267	0.006	0.736	0.132	1188	0.737
X01,0448-2423	0.007	1.51	0.174	802	1.51	X01,0863-2296	0.008	0.890	0.187	1365	0.892
X01,0448-2475	0.043	2.21	0.297	916	2.23	X01,0863-2347	0.031	1.95	0.463	1511	1.96
X01,0448-2502	0.096	2.46	0.508	1339	2.48	X01,0863-2413	0.085	2.37	0.561	1501	2.39

## Appendix. (continued).

Spot No.	ThO2 (wt %)	UO2 (wt %)	PbO (wt %)	Age (Ma)	UO2* ThO2*	Spot No.	ThO2 (wt %)	UO2 (wt %)	PbO (wt %)	Age (Ma)	UO2* ThO2*
X01,0863-2504	0.149	2.79	0.653	1481	2.83	X01,1788-3173	0.144	2.66	0.669	1573	2.70
X01,0863-2572	0.181	3.18	1.17	2128	3.22	X01,1788-3290	0.120	2.66	0.954	2096	2.69
X01,0863-2694	0.168	3.07	1.12	2125	3.11	X01,1788-3461	0.126	2.65	0.973	2134	2.68
X01,0863-2748	0.181	3.16	1.15	2106	3.21	X01,1788-3711	0.088	2.29	0.811	2077	2.31
X01,0863-2821	0.183	3.27	1.16	2074	3.31	X01,1972-3217	0.039	1.89	0.451	1520	1.90
X01,0863-2965	0.194	3.33	1.22	2129	3.38	X01,1972-3373	0.113	2.36	0.585	1561	2.39
X01,0863-3076	0.192	3.38	1.22	2106	3.43	X01,1972-3461	0.150	2.71	0.680	1571	2.75
X01,0863-3223	0.168	3.11	1.11	2092	3.15	X01,1987-3695	0.108	2.50	0.895	2092	2.53
X01,0863-3326	0.135	2.89	1.03	2085	2.93	X01,2146-3091	0.008	0.454	0.0397	616	0.457
X01,0955-2294	0.007	1.25	0.249	1304	1.26	X01,2146-3351	0.017	1.71	0.395	1484	1.71
X01,0955-2373	0.070	2.28	0.549	1528	2.30	X01,2146-3516	0.060	2.04	0.480	1500	2.05
X01,0955-2514	0.148	2.68	0.667	1560	2.72	X01,2301-3292	0.011	1.02	0.215	1375	1.02
X01,0955-2651	0.163	3.06	1.15	2172	3.10	X01,2301-3368	0.013	1.31	0.274	1360	1.32
X01,0955-2708	0.049	1.81	0.635	2067	1.83	X01,2435-3469	0.007	0.854	0.140	1103	0.856
X01,0955-2817	0.158	2.93	1.08	2138	2.98						
X01,0963-2891	0.167	3.05	1.09	2085	3.09						
X01,0963-2955	0.187	3.28	1.21	2137	3.32	Sample EG99012213					
X01,0963-3038	0.192	3.34	1.16	2039	3.39	X01,0552-0916	0.009	0.909	0.153	1128	0.912
X01,0963-3192	0.167	3.02	1.13	2160	3.07	X01,0564-0916	0.006	0.587	0.107	1205	0.588
X01,0963-3276	0.141	2.84	1.03	2103	2.88	X01,0580-0916	0.009	1.04	0.202	1275	1.04
X01,1102-2307	0.009	1.12	0.223	1309	1.12	X01,0589-0916	0.015	1.21	0.140	798	1.22
X01,1102-2413	0.051	2.17	0.524	1532	2.18	X01,0538-0925	0.006	0.573	0.0879	1037	0.575
X01,1102-2591	0.145	2.80	0.700	1567	2.84	X01,0550-0925	0.005	0.956	0.151	1064	0.957
X01,1102-3131	0.170	3.15	1.16	2128	3.20	X01,0562-0925	0.008	0.519	0.0905	1160	0.521
X01,1102-3262	0.160	2.98	1.11	2149	3.02	X01,0578-0925	0.005	1.22	0.270	1429	1.22
X01,1102-3313	0.142	2.90	1.03	2080	2.94	X01,0601-0925	0.016	1.41	0.122	612	1.41
X01,1178-2609	0.140	2.66	0.670	1575	2.70	X01,0540-0935	0.006	0.748	0.106	968	0.750
X01,1191-2870	0.158	2.99	1.09	2123	3.03	X01,0550-0935	0.008	0.921	0.150	1093	0.923
X01,1191-3148	0.167	3.11	1.11	2092	3.15	X01,0561-0935	0.010	0.641	0.0988	1039	0.644
X01,1191-3214	0.189	3.26	1.21	2147	3.30	X01,0577-0935	0.007	1.02	0.230	1448	1.03
X01,1191-3253	0.171	3.07	1.14	2146	3.12	X01,0592-0935	0.005	1.56	0.350	1446	1.56
X01,1191-3363	0.143	2.92	1.05	2103	2.96	X01,0602-0935	0.006	1.64	0.354	1402	1.64
X01,1373-2931	0.148	2.94	1.08	2132	2.98	X01,0543-0947	0.009	0.843	0.125	1005	0.846
X01,1373-2969	0.155	2.99	1.11	2156	3.03	X01,0554-0947	0.006	0.566	0.0911	1082	0.568
X01,1373-3046	0.158	3.04	1.12	2133	3.08	X01,0563-0947	0.011	0.801	0.148	1217	0.804
X01,1373-3146	0.167	3.02	1.11	2135	3.06	X01,0582-0947	0.007	1.48	0.285	1270	1.48
X01,1373-3216	0.160	3.07	1.13	2139	3.11	X01,0593-0947	0.012	2.03	0.459	1454	2.04
X01,1373-3270	0.156	3.03	1.13	2150	3.07	X01,0606-0947	0.016	2.23	0.510	1470	2.23
X01,1373-3322	0.159	2.99	1.11	2144	3.04	X01,0627-0947	0.011	2.02	0.436	1402	2.02
X01,1373-3390	0.145	2.94	1.07	2123	2.97	X01,0548-0959	0.006	0.799	0.102	877	0.801
X01,1373-3500	0.110	2.55	0.905	2077	2.58	X01,0563-0959	0.009	1.21	0.234	1270	1.22
X01,1373-3635	0.091	2.38	0.829	2051	2.41	X01,0590-0959	0.010	2.30	0.497	1404	2.30
X01,1502-2938	0.150	3.01	1.05	2055	3.05	X01,0601-0959	0.030	2.38	0.555	1492	2.39
X01,1502-2957	0.131	2.80	0.976	2052	2.83	X01,0616-0959	0.026	2.60	0.606	1489	2.61
X01,1502-2984	0.100	2.36	0.827	2063	2.38	X01,0627-0959	0.012	2.04	0.478	1502	2.04
X01,1502-3038	0.027	1.09	0.381	2069	1.09	X01,0565-0974	0.021	2.41	0.498	1349	2.41
X01,1502-3236	0.157	2.93	1.06	2115	2.97	X01,0598-0974	0.022	2.30	0.522	1461	2.30
X01,1502-3290	0.167	2.99	1.13	2173	3.04	X01,0617-0974	0.029	2.76	0.638	1482	2.77
X01,1502-3374	0.135	2.72	0.990	2118	2.75	X01,0626-0974	0.020	2.12	0.509	1530	2.12
X01,1502-3593	0.107	2.45	0.860	2060	2.48	X01,0584-0991	0.026	2.65	0.497	1237	2.66
X01,1502-3681	0.080	2.28	0.812	2087	2.30	X01,0606-0991	0.042	2.76	0.658	1520	2.77
X01,1502-3731	0.064	2.05	0.740	2111	2.07	X01,0618-0991	0.037	2.59	0.604	1490	2.60
X01,1624-2875	0.133	2.56	0.628	1544	2.59	X01,0629-0991	0.009	0.729	0.0717	690	0.732
X01,1624-2942	0.143	2.57	0.652	1586	2.61	X01,0603-1007	0.033	2.37	0.472	1303	2.38
X01,1624-2966	0.141	2.65	0.668	1580	2.68	X01,0621-1007	0.031	2.42	0.577	1521	2.43
X01,1624-3100	0.123	2.70	0.990	2132	2.73	X01,0632-1007	0.006	1.02	0.0991	684	1.02
X01,1624-3321	0.121	2.64	0.883	1983	2.68	X01,0629-1021	0.004	0.883	0.0771	618	0.884
X01,1624-3402	0.151	2.91	1.07	2140	2.95	X01,0629-1036	0.018	1.31	0.164	862	1.31
X01,1624-3533	0.121	2.61	0.959	2136	2.64	X02,0437-0224	0.009	1.04	0.142	932	1.04
X01,1624-3679	0.087	2.32	0.826	2084	2.35	X02,0430-0224	0.014	1.30	0.169	892	1.30
X01,1788-2921	0.010	0.663	0.0597	635	0.665	X02,0439-0228	0.007	0.642	0.105	1101	0.644
X01,1788-3111	0.124	2.49	0.577	1472	2.52	X02,0429-0228	0.005	0.592	0.115	1274	0.593

## Appendix. (continued).

Spot No.	ThO <sub>2</sub> (wt %)	UO <sub>2</sub> (wt %)	PbO (wt %)	Age (Ma)	UO <sub>2</sub> * ThO <sub>2</sub> *	Spot No.	ThO <sub>2</sub> (wt %)	UO <sub>2</sub> (wt %)	PbO (wt %)	Age (Ma)	UO <sub>2</sub> * ThO <sub>2</sub> *
X02,0417-0228	0.010	1.81	0.364	1318	1.81	X07,0343-0644	0.023	1.66	0.177	741	1.67
X02,0407-0228	0.009	2.33	0.467	1315	2.33	X07,0367-0644	0.175	2.81	0.549	1267	2.86
X02,0407-0236	0.019	2.16	0.376	1162	2.16	X07,0329-0652	0.208	3.28	0.642	1268	3.34
X02,0417-0236	0.013	2.23	0.410	1217	2.24	X07,0346-0652	0.222	3.21	0.826	1597	3.27
X02,0427-0236	0.005	1.79	0.379	1378	1.79	X07,0380-0652	0.391	3.80	0.913	1499	3.91
X02,0435-0236	0.009	0.683	0.112	1095	0.686	X07,0311-0663	0.203	3.34	0.927	1703	3.40
X02,0435-0244	0.011	1.89	0.186	690	1.89	X07,0370-0663	0.394	3.87	1.00	1596	3.98
X02,0426-0244	0.014	1.16	0.153	908	1.16	X07,0400-0663	0.457	3.81	1.05	1672	3.94
X02,0407-0244	0.012	0.755	0.0900	824	0.758	X07,0423-0663	0.495	4.01	1.09	1653	4.14
X03,0839-0706	0.006	1.22	0.139	790	1.22	X07,0302-0677	0.203	3.39	0.970	1748	3.44
X03,0832-0706	0.019	1.40	0.190	924	1.41	X07,0318-0677	0.341	3.67	1.00	1670	3.76
X03,0845-0711	0.009	0.766	0.126	1100	0.769	X07,0338-0677	0.370	3.85	0.967	1557	3.95
X03,0829-0711	0.010	0.704	0.127	1199	0.707	X07,0365-0677	0.543	4.21	1.06	1551	4.36
X03,0820-0711	0.006	0.696	0.117	1121	0.698	X07,0392-0677	0.463	3.83	1.07	1694	3.96
X03,0816-0719	0.007	0.649	0.139	1384	0.651	X07,0423-0677	0.466	3.83	0.942	1522	3.96
X03,0838-0719	0.006	0.679	0.106	1053	0.681	X07,0495-0677	0.608	4.62	1.18	1569	4.79
X03,0851-0724	0.011	0.864	0.154	1180	0.867	X07,0282-0691	0.095	2.35	0.441	1227	2.38
X03,0838-0724	0.004	0.792	0.141	1185	0.793	X07,0301-0691	0.239	3.51	0.993	1730	3.57
X03,0818-0724	0.004	0.718	0.131	1206	0.719	X07,0324-0691	0.357	3.63	1.05	1749	3.72
X03,0829-0731	0.010	0.751	0.171	1462	0.754	X07,0324-0691	0.360	3.78	1.04	1678	3.88
X03,0836-0731	0.008	0.827	0.159	1263	0.829	X07,0348-0691	0.516	4.52	1.33	1773	4.65
X04,0770-0853	0.011	1.06	0.0728	492	1.06	X07,0365-0691	0.578	4.84	1.40	1741	5.00
X04,0785-0839	0.016	1.83	0.178	684	1.84	X07,0382-0691	0.470	3.94	1.09	1676	4.07
X04,0771-0855	0.013	1.01	0.0766	539	1.02	X07,0402-0691	0.436	3.68	1.04	1711	3.80
X05,0188-0047	0.174	3.43	0.941	1694	3.47	X07,0423-0691	0.582	4.36	1.25	1718	4.52
X05,0195-0047	0.184	3.47	0.969	1717	3.52	X07,0481-0691	0.525	4.21	0.860	1297	4.36
X05,0195-0053	0.205	3.72	1.04	1716	3.77	X07,0516-0691	0.524	4.44	1.08	1508	4.59
X05,0191-0053	0.201	3.65	1.03	1728	3.71	X07,0274-0707	0.079	2.81	0.724	1615	2.83
X06,1017-0907	0.030	1.85	0.179	680	1.86	X07,0309-0707	0.331	3.45	1.00	1758	3.54
X06,1006-0912	0.026	1.61	0.185	792	1.62	X07,0335-0707	0.399	3.70	1.14	1833	3.81
X06,1013-0912	0.026	1.83	0.197	749	1.84	X07,0374-0707	0.508	4.20	1.22	1746	4.34
X06,1021-0912	0.025	1.73	0.173	703	1.73	X07,0400-0707	0.646	5.19	1.42	1658	5.36
X06,1027-0912	0.017	1.27	0.143	781	1.27	X07,0433-0707	0.634	4.35	1.32	1806	4.52
X06,1008-0919	0.032	1.75	0.177	705	1.76	X07,0464-0707	0.599	4.58	1.10	1494	4.74
X06,1019-0919	0.023	1.54	0.181	812	1.55	X07,0501-0707	0.306	3.40	0.599	1148	3.49
X06,1027-0919	0.030	1.89	0.205	754	1.90	X07,0529-0707	0.203	2.97	0.490	1089	3.03
X06,0973-0927	0.009	1.03	0.107	731	1.03	X07,0280-0721	0.068	2.85	0.836	1795	2.87
X06,0983-0927	0.010	0.775	0.0768	694	0.778	X07,0294-0721	0.102	2.93	0.851	1777	2.96
X06,0991-0927	0.011	0.956	0.109	793	0.959	X07,0317-0721	0.335	3.61	1.04	1753	3.70
X06,1013-0927	0.020	1.38	0.152	765	1.39	X07,0334-0721	0.362	3.64	1.10	1806	3.74
X06,1025-0927	0.021	1.85	0.199	750	1.85	X07,0358-0721	0.336	3.36	0.799	1487	3.45
X06,1030-0927	0.008	1.07	0.0994	652	1.08	X07,0382-0721	0.448	4.04	1.22	1810	4.16
X06,0966-0939	0.007	0.609	0.0492	573	0.611	X07,0405-0721	0.569	4.24	1.19	1693	4.40
X06,0979-0939	0.004	0.756	0.0621	584	0.757	X07,0439-0721	0.415	3.63	1.05	1744	3.75
X06,0998-0939	0.010	1.18	0.147	861	1.18	X07,0470-0721	0.376	3.88	1.04	1642	3.98
X06,1003-0939	0.006	1.24	0.137	768	1.24	X07,0506-0721	0.249	3.60	0.837	1470	3.67
X06,1016-0939	0.016	1.22	0.125	712	1.23	X07,0528-0721	0.182	3.24	0.794	1539	3.29
X06,1030-0939	0.018	1.56	0.165	738	1.57	X07,0320-0744	0.086	2.95	0.852	1775	2.97
X06,0959-0951	0.005	0.744	0.0752	709	0.745	X07,0339-0744	0.111	2.97	0.866	1786	2.99
X06,0970-0951	0.006	0.540	0.0622	798	0.542	X07,0365-0744	0.300	3.60	1.09	1817	3.68
X06,0981-0951	0.010	0.687	0.0861	863	0.690	X07,0393-0744	0.328	3.44	0.997	1755	3.52
X06,0994-0951	0.014	1.15	0.127	768	1.15	X07,0416-0744	0.360	3.68	1.04	1719	3.78
X06,1006-0951	0.009	1.31	0.142	754	1.32	X07,0439-0744	0.275	3.56	0.937	1625	3.64
X06,1020-0951	0.030	2.05	0.220	748	2.06	X07,0365-0761	0.046	2.54	0.649	1609	2.55
X06,1036-0951	0.027	1.27	0.128	700	1.28	X07,0383-0761	0.055	2.70	0.703	1632	2.72
X06,0975-0965	0.012	1.08	0.108	702	1.08	X08,0565-0872	0.003	1.29	0.136	736	1.29
X06,0986-0965	0.006	1.03	0.113	762	1.03	X08,0578-0872	0.004	1.82	0.178	685	1.83
X06,0997-0965	0.014	1.36	0.134	693	1.36	X08,0578-0890	0.004	1.36	0.271	1306	1.36
X06,0003-0965	0.017	1.49	0.161	754	1.50	X08,0587-0825	0.008	0.851	0.100	816	0.853
X06,0981-0976	0.009	0.964	0.102	741	0.967	X08,0587-0875	0.004	0.341	0.0361	739	0.342
X06,0990-0976	0.008	1.29	0.141	760	1.29	X08,0587-0901	0.007	1.44	0.264	1215	1.44
X06,0990-0983	0.015	1.03	0.107	727	1.03	X08,0608-0805	0.005	0.954	0.0986	724	0.955

Appendix. (continued).

Spot No.	ThO <sub>2</sub> (wt %)	UO <sub>2</sub> (wt %)	PbO (wt %)	Age (Ma)	UO <sub>2</sub> * ThO <sub>2</sub> *	Spot No.	ThO <sub>2</sub> (wt %)	UO <sub>2</sub> (wt %)	PbO (wt %)	Age (Ma)	UO <sub>2</sub> * ThO <sub>2</sub> *
X08,0608-0825	0.010	1.13	0.162	971	1.14	X09,0183-0181	0.080	2.85	0.749	1643	2.87
X08,0608-0841	0.006	1.08	0.169	1058	1.08	X09,0183-0217	0.157	3.21	0.848	1641	3.25
X08,0608-0885	0.013	1.07	0.126	813	1.08	X09,0183-0278	0.230	3.50	0.924	1636	3.56
X08,0604-0757	0.009	1.15	0.155	923	1.15	X09,0183-0333	0.222	3.46	0.933	1663	3.52
X08,0624-0762	0.029	1.93	0.183	665	1.94	X09,0222-0047	0.022	2.80	0.669	1523	2.81
X08,0624-0776	0.007	0.998	0.131	903	0.999	X09,0222-0106	0.052	2.85	0.726	1604	2.86
X08,0624-0796	0.007	0.938	0.139	1008	0.940	X09,0222-0155	0.084	2.85	0.733	1613	2.87
X08,0624-0807	0.005	0.936	0.137	993	0.938	X09,0222-0193	0.110	2.59	0.682	1637	2.62
X08,0624-0828	0.011	0.955	0.173	1198	0.958	X09,0222-0208	0.152	3.20	0.842	1636	3.24
X08,0624-0844	0.008	1.06	0.211	1302	1.06	X09,0222-0240	0.203	3.27	0.857	1626	3.33
X08,0624-0894	0.007	0.989	0.103	725	0.991	X09,0222-0283	0.297	3.72	1.01	1670	3.80
X08,0624-0914	0.014	1.30	0.217	1113	1.31	X09,0222-0344	0.299	3.83	1.02	1639	3.91
X08,0642-0767	0.004	1.25	0.127	713	1.25	X09,0259-0986	0.006	1.28	0.127	695	1.29
X08,0642-0849	0.010	1.11	0.216	1276	1.12	X09,0259-0017	0.010	2.45	0.564	1480	2.45
X08,0642-0900	0.006	1.28	0.243	1253	1.28	X09,0259-0048	0.033	2.96	0.705	1516	2.97
X08,0642-0920	0.007	1.20	0.229	1257	1.20	X09,0259-0080	0.044	2.97	0.734	1564	2.98
X08,0642-0940	0.009	1.05	0.118	781	1.06	X09,0259-0123	0.074	2.76	0.697	1589	2.78
X08,0642-0985	0.009	0.994	0.163	1102	0.997	X09,0259-0166	0.140	3.12	0.801	1604	3.16
X08,0671-0763	0.004	1.04	0.108	724	1.05	X09,0259-0198	0.148	2.88	0.742	1609	2.92
X08,0671-0782	0.009	1.09	0.146	917	1.10	X09,0259-0278	0.400	4.01	1.09	1661	4.12
X08,0671-0801	0.004	1.14	0.113	695	1.14	X09,0259-0319	0.369	3.98	1.07	1654	4.08
X08,0671-0835	0.009	1.16	0.193	1112	1.16	X09,0259-0340	0.235	3.16	0.779	1539	3.23
X08,0671-0884	0.007	1.21	0.233	1268	1.21	X09,0306-0033	0.031	2.87	0.677	1506	2.88
X08,0671-0956	0.009	0.988	0.175	1180	0.990	X09,0306-0073	0.062	3.03	0.766	1593	3.05
X08,0692-0800	0.006	0.991	0.147	1009	0.992	X09,0306-0195	0.218	3.38	0.878	1611	3.44
X08,0692-0837	0.013	1.06	0.161	1031	1.06	X09,0306-0262	0.394	4.20	1.13	1645	4.31
X08,0692-0875	0.012	1.12	0.195	1163	1.12	X09,0347-0137	0.010	0.780	0.0599	547	0.783
X08,0710-0878	0.011	0.730	0.127	1157	0.733	X09,0347-0195	0.015	3.52	0.325	653	3.52
X08,0701-0833	0.011	0.946	0.153	1085	0.950	X09,0263-0154	0.135	3.34	0.856	1603	3.38
X08,0672-0833	0.011	1.15	0.193	1117	1.16	X09,0230-0154	0.105	3.05	0.765	1575	3.08
X08,0624-0833	0.005	1.10	0.176	1077	1.10	X09,0189-0172	0.080	2.87	0.731	1599	2.89
X08,0601-0833	0.003	1.23	0.164	911	1.24	X09,0214-0172	0.138	3.35	0.861	1607	3.39
X08,0632-0916	0.008	1.26	0.207	1099	1.26	X09,0245-0172	0.140	3.07	0.784	1597	3.11
X08,0625-0828	0.014	1.000	0.150	1016	1.00	X09,0280-0187	0.167	3.15	0.811	1606	3.19
X08,0625-0780	0.004	0.949	0.105	769	0.950	X09,0240-0187	0.129	2.87	0.736	1602	2.91
X08,0628-0906	0.008	1.35	0.207	1038	1.35	X09,0203-0187	0.143	3.24	0.828	1600	3.28
X08,0637-0930	0.014	1.20	0.184	1037	1.20	X09,0126-0293	0.025	2.82	0.607	1396	2.82
X08,0658-0803	0.010	1.21	0.189	1051	1.22	X09,0161-0293	0.089	3.06	0.761	1567	3.09
X08,0699-0860	0.005	0.997	0.145	987	0.999	X09,0184-0293	0.144	3.11	0.830	1654	3.15
X08,0699-0877	0.010	0.893	0.154	1152	0.896	X09,0208-0293	0.217	3.58	0.929	1613	3.64
X08,0681-0965	0.010	0.849	0.133	1055	0.852	X09,0244-0293	0.325	4.05	1.10	1668	4.14
X08,0620-0918	0.014	1.34	0.201	1017	1.34	X09,0259-0293	0.230	2.67	0.551	1319	2.74
X09,0080-0271	0.022	2.04	0.258	869	2.04	X09,0282-0293	0.388	4.12	1.17	1723	4.22
X09,0081-0296	0.030	2.62	0.551	1364	2.63	X09,0297-0293	0.402	4.16	1.17	1713	4.27
X09,0101-0236	0.017	1.93	0.289	1013	1.94	X09,0340-0293	0.471	4.38	1.14	1595	4.51
X09,0101-0262	0.027	2.15	0.353	1102	2.15	X09,0349-0264	0.465	4.76	1.29	1661	4.89
X09,0101-0310	0.054	2.67	0.574	1391	2.68	X09,0325-0264	0.166	1.63	0.207	853	1.68
X09,0101-0348	0.010	0.709	0.0560	561	0.712	X09,0288-0264	0.320	3.95	1.09	1696	4.03
X09,0101-0378	0.011	0.741	0.0570	547	0.744	X09,0265-0264	0.292	3.84	1.09	1726	3.92
X09,0123-0209	0.032	2.43	0.497	1333	2.44	X09,0249-0264	0.261	3.76	1.03	1685	3.83
X09,0123-0255	0.055	2.63	0.675	1614	2.64	X09,0227-0264	0.225	3.64	1.00	1692	3.70
X09,0123-0296	0.086	2.91	0.741	1600	2.93	X09,0194-0164	0.204	3.50	0.955	1683	3.55
X09,0123-0321	0.098	2.94	0.594	1315	2.96	X09,0167-0264	0.078	2.76	0.722	1634	2.79
X09,0123-0348	0.080	2.64	0.350	903	2.66	X09,0147-0264	0.041	2.55	0.485	1252	2.56
X09,0147-0181	0.042	1.87	0.195	727	1.88	X09,0149-0246	0.027	2.35	0.576	1554	2.36
X09,0147-0226	0.089	2.93	0.759	1623	2.95	X09,0174-0246	0.072	2.79	0.734	1644	2.81
X09,0147-0268	0.195	3.41	0.888	1619	3.46	X09,0191-0246	0.122	3.18	0.848	1657	3.22
X09,0147-0308	0.145	2.99	0.735	1547	3.03	X09,0206-0246	0.208	3.54	0.980	1702	3.60
X09,0147-0354	0.085	3.79	0.346	642	3.81	X09,0238-0246	0.225	3.54	0.967	1680	3.61
X09,0147-0385	0.051	2.88	0.258	632	2.89	X09,0260-0246	0.240	3.55	0.920	1609	3.62
X09,0183-0102	0.034	2.08	0.236	789	2.08	X09,0278-0246	0.250	3.65	1.02	1715	3.72
X09,0183-0144	0.029	2.53	0.625	1567	2.53	X09,0295-0246	0.267	3.80	1.05	1691	3.87

## Appendix. (continued).

Spot No.	ThO2 (wt %)	UO2 (wt %)	PbO (wt %)	Age (Ma)	UO2* ThO2*	Spot No.	ThO2 (wt %)	UO2 (wt %)	PbO (wt %)	Age (Ma)	UO2* ThO2*
X09,0347-0246	0.347	4.04	1.03	1582	4.14	X10,1061-1043	0.310	3.59	1.01	1708	3.68
X09,0269-0220	0.173	3.48	0.962	1704	3.52	X10,1061-1092	0.061	1.71	0.195	787	1.72
X09,0237-0220	0.202	3.82	1.05	1691	3.88	X10,1093-0822	0.041	2.11	0.444	1365	2.12
X10,0964-0911	0.049	2.47	0.465	1241	2.48	X10,1093-0854	0.165	3.28	0.873	1653	3.32
X10,0964-0930	0.104	3.21	0.872	1684	3.24	X10,1093-0875	0.213	3.63	0.996	1691	3.68
X10,0964-0950	0.192	3.71	1.01	1689	3.76	X10,1093-0900	0.272	3.95	1.08	1683	4.03
X10,0964-0980	0.438	4.26	1.22	1733	4.38	X10,1093-0919	0.257	3.63	1.00	1696	3.70
X10,0964-1006	0.490	4.31	1.24	1738	4.44	X10,1093-0952	0.250	3.63	1.00	1698	3.70
X10,0964-1032	0.032	1.88	0.206	763	1.88	X10,1093-0997	0.249	3.59	0.985	1684	3.66
X10,0975-0872	0.007	1.68	0.168	701	1.69	X10,1115-0802	0.020	1.84	0.193	734	1.84
X10,0975-0895	0.324	4.24	1.20	1729	4.33	X10,1115-0843	0.159	3.50	0.907	1615	3.55
X10,0975-0917	0.405	4.61	1.32	1739	4.72	X10,1115-0863	0.153	3.27	0.895	1690	3.32
X10,0975-0962	0.488	4.52	1.30	1732	4.66	X10,1115-0916	0.093	2.96	0.784	1648	2.99
X10,0975-0987	0.469	4.44	1.17	1616	4.57	X10,1115-0946	0.038	2.61	0.660	1597	2.62
X10,0975-1013	0.495	4.47	1.29	1740	4.61						
X10,0975-1039	0.428	3.69	0.840	1427	3.81						
X10,0975-1056	0.317	3.41	0.677	1274	3.50						
X10,0999-0774	0.004	1.62	0.155	674	1.62						
X10,0999-0797	0.047	1.99	0.221	771	2.00						
X10,0999-0820	0.167	3.38	0.946	1722	3.42						
X10,0999-0848	0.305	4.34	1.21	1711	4.43						
X10,0999-0872	0.285	3.87	1.11	1748	3.95						
X10,0999-0897	0.344	4.38	1.24	1727	4.48						
X10,0999-0921	0.351	4.37	1.22	1708	4.47						
X10,0999-0946	0.464	4.40	1.26	1726	4.53						
X10,0999-0979	0.628	5.59	1.60	1729	5.76						
X10,0999-1021	0.556	4.71	1.22	1589	4.86						
X10,0999-1045	0.554	4.79	1.35	1705	4.94						
X10,0999-1090	0.034	1.71	0.182	740	1.72						
X10,1020-0774	0.007	1.85	0.199	750	1.86						
X10,1020-0793	0.114	2.91	0.777	1662	2.94						
X10,1020-0812	0.162	3.36	0.921	1693	3.40						
X10,1020-0839	0.260	4.02	1.13	1715	4.09						
X10,1020-0861	0.260	3.72	1.03	1699	3.79						
X10,1020-0895	0.310	4.18	1.16	1701	4.27						
X10,1020-0927	0.359	4.30	1.20	1703	4.40						
X10,1020-0968	0.357	3.61	0.760	1339	3.71						
X10,1020-0990	0.425	4.15	1.12	1655	4.26						
X10,1020-1019	0.553	4.75	1.34	1711	4.90						
X10,1020-1049	0.588	4.66	1.17	1546	4.82						
X10,1020-1072	0.616	4.34	1.09	1543	4.51						
X10,1020-1101	0.019	1.79	0.181	710	1.79						
X10,1041-0771	0.006	1.76	0.179	710	1.77						
X10,1041-0810	0.133	3.16	0.863	1689	3.20						
X10,1041-0830	0.166	3.31	0.905	1688	3.35						
X10,1041-0850	0.238	3.90	1.02	1618	3.97						
X10,1041-0871	0.253	3.70	1.01	1677	3.77						
X10,1041-0912	0.344	4.56	1.26	1689	4.65						
X10,1041-0942	0.363	3.95	0.992	1560	4.05						
X10,1041-0984	0.478	4.47	1.23	1680	4.60						
X10,1041-1010	0.449	4.25	1.20	1708	4.38						
X10,1041-1034	0.495	4.47	1.19	1632	4.60						
X10,1041-1066	0.472	4.28	1.19	1692	4.41						
X10,1061-0774	0.016	1.86	0.191	721	1.86						
X10,1061-0824	0.151	3.21	0.855	1652	3.25						
X10,1061-0845	0.187	3.43	0.930	1676	3.48						
X10,1061-0869	0.231	3.76	1.01	1661	3.82						
X10,1061-0891	0.288	4.28	1.15	1651	4.36						
X10,1061-0930	0.298	3.90	1.09	1703	3.98						
X10,1061-0956	0.316	3.81	1.01	1633	3.89						
X10,1061-0983	0.325	3.78	1.05	1702	3.87						
X10,1061-1012	0.305	3.29	0.973	1783	3.37						



*Appendix. (continued).*

Spot No.	ThO <sub>2</sub> (wt %)	UO <sub>2</sub> (wt %)	PbO (wt %)	Age (Ma)	UO <sub>2</sub> * ThO <sub>2</sub> *	Spot No.	ThO <sub>2</sub> (wt %)	UO <sub>2</sub> (wt %)	PbO (wt %)	Age (Ma)	UO <sub>2</sub> * ThO <sub>2</sub> *
M1,3528-1934	7.85	0.277	0.522	1360	8.83	M2,4132-2242	6.97	0.446	0.539	1445	8.57
M1,3468-1934	7.82	0.284	0.592	1534	8.85	M2,4078-2242	7.21	0.286	0.612	1691	8.26
M1,3407-1934	7.78	0.278	0.598	1559	8.79	M2,3929-2242	7.71	0.438	0.473	1181	9.25
M1,3312-1934	7.82	0.278	0.519	1356	8.81	M2,4118-2263	5.83	0.462	0.519	1581	7.51
M1,3200-1934	7.79	0.289	0.596	1543	8.84	M2,4077-2263	7.22	0.295	0.521	1445	8.28
M1,3147-1934	7.80	0.314	0.543	1399	8.92	M2,3944-2263	7.60	0.320	0.433	1150	8.71
M1,3097-1934	7.51	0.525	0.493	1218	9.36	M2,3811-2263	7.78	0.375	0.418	1068	9.08
M1,3037-1934	8.36	0.616	0.464	1026	10.5	M2,4082-2329	7.53	0.365	0.444	1165	8.81
M1,3669-2032	8.15	0.581	0.563	1273	10.2	M2,4027-2329	7.48	0.306	0.450	1215	8.55
M1,3620-2032	7.27	0.404	0.600	1571	8.74	M2,3936-2329	7.50	0.317	0.423	1137	8.61
M1,3554-2032	7.93	0.301	0.595	1512	9.02	M2,3877-2329	7.64	0.328	0.368	975	8.77
M1,3503-2032	7.80	0.323	0.550	1413	8.96	M2,3822-2329	7.66	0.346	0.439	1146	8.87
M1,3414-2032	7.74	0.268	0.651	1703	8.73	M2,4053-2388	7.33	0.336	0.424	1153	8.51
M1,3314-2032	7.69	0.270	0.455	1216	8.64	M2,4016-2388	7.33	0.329	0.401	1097	8.47
M1,3231-2032	7.83	0.265	0.635	1649	8.80	M2,3956-2388	7.31	0.308	0.445	1224	8.39
M1,3174-2032	7.76	0.272	0.635	1657	8.76	M2,3893-2388	7.43	0.322	0.417	1129	8.55
M1,3063-2032	7.83	0.293	0.435	1138	8.85	M2,3832-2388	7.43	0.343	0.430	1153	8.62
M1,3008-2032	8.09	0.532	0.519	1204	9.96	M2,4036-2431	7.24	0.330	0.413	1140	8.39
M1,3660-2160	7.29	0.453	0.515	1333	8.90	M2,3970-2431	7.29	0.332	0.338	934	8.43
M1,3581-2160	7.60	0.283	0.649	1713	8.64	M2,4033-2470	7.24	0.337	0.513	1399	8.44
M1,3501-2160	7.79	0.299	0.497	1295	8.84	M2,4096-2365	7.22	0.481	0.620	1582	8.97
M1,3418-2160	7.55	0.271	0.556	1497	8.53	M2,4096-2384	6.89	0.537	0.634	1637	8.86
M1,3261-2160	7.69	0.283	0.617	1619	8.72	M2,4096-2426	7.16	0.617	0.703	1701	9.44
M1,3166-2160	7.70	0.309	0.609	1579	8.82	M2,4096-2465	7.35	0.629	0.585	1403	9.60
M1,3095-2160	7.81	0.292	0.525	1365	8.85	M2,4122-2324	7.08	0.482	0.593	1537	8.83
M1,3729-2290	7.62	0.354	0.384	1008	8.84	M2,4122-2349	7.21	0.605	0.653	1587	9.41
M1,3669-2290	7.28	0.316	0.535	1458	8.42	M2,4122-2466	7.19	0.612	0.548	1348	9.37
M1,3554-2290	7.71	0.285	0.630	1645	8.76	M2,4122-2496	7.00	0.557	0.400	1041	8.92
M1,3470-2290	7.68	0.276	0.661	1732	8.70	M2,4164-2303	6.86	0.548	0.635	1638	8.86
M1,3333-2290	7.64	0.269	0.657	1735	8.64	M2,4164-2358	6.83	0.561	0.633	1629	8.88
M1,3239-2290	7.70	0.298	0.490	1292	8.75	M2,4164-2400	6.78	0.525	0.561	1486	8.67
M1,3139-2290	7.60	0.310	0.499	1320	8.70	M2,4164-2456	7.60	0.410	0.472	1207	9.04
M1,3734-2423	7.99	0.484	0.334	810	9.62	M3,1227-8732	9.29	0.873	0.447	851	12.3
M1,3670-2423	7.53	0.282	0.419	1138	8.51	M3,1227-8752	10.0	0.555	0.427	837	11.9
M1,3561-2423	7.52	0.276	0.522	1411	8.51	M3,1227-8795	9.35	0.805	0.390	756	12.1
M1,3460-2423	7.71	0.290	0.565	1480	8.76	M3,1258-8726	11.5	0.552	0.447	779	13.4
M1,3355-2423	7.43	0.286	0.548	1485	8.46	M3,1255-8748	28.5	0.819	0.523	394	31.2
M1,3208-2423	7.54	0.292	0.626	1660	8.61	M3,1255-8789	10.1	0.531	0.496	967	11.9
M1,3151-2423	7.49	0.509	0.564	1395	9.31	M3,1255-8840	9.29	0.849	0.517	983	12.2
M1,3748-2488	7.63	0.307	0.379	1013	8.69	M3,1255-8870	9.33	0.732	0.521	1020	11.9
M1,3682-2488	7.53	0.288	0.465	1256	8.54	M3,1289-8722	9.72	0.819	0.382	716	12.5
M1,3609-2488	7.54	0.285	0.378	1028	8.53	M3,1289-8852	28.5	0.864	0.487	366	31.4
M1,3508-2488	7.48	0.261	0.496	1358	8.40	M3,1289-8794	42.5	0.991	0.556	287	45.8
M1,3422-2488	7.58	0.330	0.401	1066	8.72	M3,1289-8855	8.76	0.774	0.517	1048	11.4
M1,3347-2488	7.35	0.281	0.632	1719	8.39	M3,1289-8945	11.3	0.589	0.487	851	13.3
M1,3280-2488	7.50	0.277	0.555	1497	8.50	M3,1340-8727	9.26	0.844	0.440	846	12.1
M1,3217-2488	7.85	0.291	0.404	1059	8.85	M3,1340-8766	9.49	0.855	0.461	866	12.4
M1,3710-2579	7.40	0.269	0.341	954	8.32	M3,1340-8814	9.76	0.832	0.437	810	12.6
M1,3655-2579	7.41	0.269	0.462	1273	8.36	M3,1340-8908	10.3	0.552	0.509	973	12.2
M2,4048-2127	7.11	0.304	0.557	1555	8.21	M3,1340-9011	10.4	0.526	0.419	803	12.2
M2,4017-2136	7.42	0.277	0.524	1431	8.42	M3,1295-8737	8.96	0.544	0.483	1034	10.8
M2,4093-2172	7.04	0.326	0.559	1557	8.23	M3,1395-8889	9.47	0.456	0.555	1161	11.1
M2,4051-2172	7.02	0.293	0.656	1840	8.11	M3,1395-8941	9.50	0.609	0.453	910	11.6
M2,3987-2172	7.41	0.304	0.613	1643	8.52	M3,1395-9047	25.6	0.404	0.603	526	26.9
M2,3951-2172	7.37	0.282	0.524	1436	8.38	M3,1395-9120	11.1	0.657	0.531	925	13.4
M2,4173-2195	6.25	0.475	0.337	994	7.88	M3,1452-8754	10.00	0.609	0.386	749	12.0
M2,4131-2195	6.29	0.513	0.573	1606	8.16	M3,1452-8787	9.85	0.490	0.423	857	11.5
M2,4085-2195	6.96	0.314	0.666	1861	8.14	M3,1452-8827	9.42	0.425	0.519	1103	10.9
M2,4046-2195	7.49	0.287	0.676	1798	8.56	M3,1452-8871	9.49	0.425	0.578	1216	11.0
M2,3973-2195	7.62	0.292	0.474	1264	8.65	M3,1452-8984	9.33	0.426	0.546	1167	10.8
M2,3939-2195	7.65	0.296	0.533	1408	8.71	M3,1452-9095	27.2	0.396	0.565	467	28.5
M2,4162-2242	6.57	0.510	0.488	1339	8.38	M3,1452-9163	9.44	0.570	0.421	862	11.4

## Appendix. (continued).

Spot No.	ThO <sub>2</sub> (wt %)	UO <sub>2</sub> (wt %)	PbO (wt %)	Age (Ma)	UO <sub>2</sub> * ThO <sub>2</sub> *	Spot No.	ThO <sub>2</sub> (wt %)	UO <sub>2</sub> (wt %)	PbO (wt %)	Age (Ma)	UO <sub>2</sub> * ThO <sub>2</sub> *
M3,1553-8820	6.33	0.592	0.331	922	8.35	M4,1527-0663	8.76	0.308	0.654	1519	9.87
M3,1553-8908	9.36	0.390	0.454	985	10.7	M4,1480-0663	8.78	0.320	0.674	1553	9.94
M3,1553-8957	9.55	0.384	0.494	1054	10.9	M4,1430-0663	8.67	0.280	0.588	1398	9.67
M3,1553-9020	9.22	0.387	0.554	1210	10.6	M4,1361-0663	8.98	0.281	0.543	1258	9.97
M3,1553-9081	9.24	0.373	0.546	1196	10.5	M4,1278-0663	25.8	0.292	0.558	489	26.8
M3,1553-9138	9.36	0.391	0.551	1186	10.7	M4,1185-0663	9.43	0.452	0.610	1276	11.0
M3,1553-9219	11.4	0.952	0.416	669	14.5	M4,1237-0727	9.25	0.461	0.563	1197	10.9
M3,1650-8879	9.29	0.411	0.380	830	10.7	M4,1301-0727	8.80	0.295	0.529	1240	9.84
M3,1650-8997	9.32	0.388	0.531	1152	10.7	M4,1360-0727	8.62	0.275	0.523	1258	9.59
M3,1650-9069	9.27	0.382	0.523	1142	10.6	M4,1409-0727	8.57	0.303	0.534	1276	9.64
M3,1650-9138	9.36	0.394	0.470	1018	10.7	M4,1448-0727	8.38	0.308	0.514	1252	9.47
M3,1650-9219	9.26	0.386	0.563	1225	10.6	M4,1486-0727	8.26	0.304	0.510	1261	9.33
M3,1650-9331	9.55	0.808	0.342	653	12.3	M4,1531-0727	8.23	0.348	0.386	953	9.42
M3,1693-8898	9.70	0.399	0.553	1153	11.1	M4,1441-0769	8.30	0.346	0.434	1059	9.50
M3,1693-8958	9.55	0.409	0.299	642	10.9	M4,1361-0769	8.28	0.322	0.502	1231	9.42
M3,1693-9077	9.54	0.378	0.625	1323	10.9	M4,1307-0769	8.59	0.566	0.434	959	10.5
M3,1693-9159	9.33	0.400	0.617	1322	10.7	M4,1696-0711	8.48	0.588	0.485	1068	10.5
M3,1693-9209	9.50	0.403	0.557	1180	10.9	M5,1542-1183	8.64	0.677	0.497	1050	11.0
M3,1693-9284	9.68	0.513	0.386	789	11.4	M5,1568-1206	7.77	0.449	0.495	1224	9.35
M3,1693-9386	10.0	0.774	0.319	593	12.6	M5,1518-1206	7.51	0.322	0.590	1555	8.68
M3,1746-8928	7.15	0.605	0.447	1118	9.26	M5,1454-1206	7.88	0.317	0.481	1234	8.99
M3,1746-8970	9.56	0.404	0.392	836	10.9	M5,1660-1223	7.59	0.477	0.247	629	9.18
M3,1746-9189	9.50	0.385	0.516	1103	10.8	M5,1582-1223	7.89	0.410	0.329	826	9.28
M3,1746-9243	9.23	0.385	0.640	1388	10.6	M5,1534-1223	7.72	0.327	0.551	1425	8.89
M3,1746-9326	9.06	0.463	0.413	904	10.6	M5,1478-1223	8.26	0.367	0.463	1122	9.54
M3,1746-9390	9.61	0.510	0.279	579	11.3	M5,1436-1223	7.86	0.311	0.441	1142	8.94
M3,1746-9565	9.68	0.414	0.431	904	11.1	M5,1423-1250	7.85	0.317	0.427	1104	8.95
M3,1831-8997	9.49	0.414	0.479	1019	10.9	M5,1459-1250	7.95	0.320	0.400	1023	9.06
M3,1831-9044	9.43	0.384	0.537	1152	10.8	M5,1512-1250	7.93	0.310	0.459	1178	9.02
M3,1831-9090	9.54	0.403	0.616	1295	11.0	M5,1567-1250	7.43	0.352	0.556	1467	8.70
M3,1831-9160	9.55	0.403	0.597	1256	11.0	M5,1619-1250	6.55	0.525	0.430	1185	8.39
M3,1906-9042	9.69	0.435	0.431	898	11.2	M5,1658-1250	6.94	0.416	0.219	616	8.32
M3,1906-9143	10.4	0.465	0.448	871	12.0	M5,1623-1301	6.72	0.501	0.476	1292	8.49
M3,1807-9517	10.2	0.437	0.365	730	11.7	M5,1564-1301	7.28	0.307	0.460	1269	8.36
M3,1758-9403	9.36	0.500	0.399	842	11.1	M5,1415-1301	8.06	0.471	0.376	905	9.67
M3,1848-9208	9.90	0.395	0.470	971	11.3	M5,1322-1403	8.05	0.380	0.358	893	9.35
M4,1685-0443	10.3	0.547	0.321	621	12.1	M5,1394-1403	7.95	0.341	0.322	825	9.11
M4,1711-0458	9.84	0.476	0.537	1083	11.5	M5,1531-1423	7.76	0.334	0.318	835	8.89
M4,1672-0458	9.56	0.590	0.384	776	11.6	M5,1474-1484	7.50	0.365	0.303	809	8.74
M4,1721-0534	9.33	0.440	0.472	1010	10.9	M5,1529-1484	7.40	0.353	0.305	828	8.60
M4,1666-0534	12.6	0.481	0.443	731	14.2	M5,1529-1441	7.47	0.344	0.344	925	8.65
M4,1564-0534	10.2	0.716	0.545	1001	12.6	M5,1613-1512	8.15	0.666	0.421	938	10.4
M4,1503-0534	9.04	0.325	0.588	1329	10.2	M5,1453-1482	7.71	0.336	0.281	742	8.84
M4,1451-0534	9.25	0.326	0.661	1457	10.4	M5,1611-1716	7.73	0.569	0.334	807	9.66
M4,1365-0534	9.11	0.352	0.710	1565	10.4	M5,1623-1828	7.44	0.518	0.266	677	9.18
M4,1240-0534	9.15	0.572	0.568	1179	11.1	M5,1547-1828	8.25	0.758	0.296	643	10.8
M4,1170-0534	9.49	0.627	0.572	1135	11.7	M5,1530-1772	7.37	0.444	0.344	900	8.89
M4,1358-0477	27.5	0.374	0.601	491	28.8	M5,1563-1732	8.57	0.677	0.362	778	10.9
M4,1452-0477	26.2	0.331	0.590	509	27.3	M5,1609-1609	8.20	0.490	0.292	693	9.84
M4,1178-0609	9.30	0.557	0.586	1202	11.3	M5,1578-1645	7.90	0.570	0.323	769	9.82
M4,1226-0609	9.49	0.500	0.546	1125	11.2	M5,1461-1560	8.19	0.363	0.257	641	9.40
M4,1343-0609	9.23	0.350	0.620	1363	10.5	M6,9446-3497	9.98	0.635	0.402	774	12.1
M4,1404-0609	9.17	0.348	0.620	1370	10.4	M6,9439-3501	9.38	0.634	0.485	975	11.6
M4,1460-0609	9.00	0.333	0.620	1398	10.2	M6,9435-3511	8.79	0.566	0.400	870	10.7
M4,1527-0609	8.39	0.313	0.464	1133	9.48	M6,9437-3525	9.07	0.667	0.358	739	11.3
M4,1603-0609	9.08	0.330	0.606	1361	10.3	M6,9443-3525	9.90	0.593	0.357	702	11.9
M4,1730-0609	9.25	0.318	0.478	1071	10.3	M6,9467-3389	9.99	0.642	0.552	1049	12.2
M4,1779-0609	9.80	0.518	0.321	651	11.5	M6,9456-3389	9.92	0.594	0.500	972	12.0
M4,1751-0663	7.65	0.472	0.292	738	9.23	M6,9473-3401	10.2	0.825	0.627	1114	13.0
M4,1693-0663	7.67	0.477	0.472	1168	9.34	M6,9462-3401	9.62	0.579	0.520	1038	11.6
M4,1630-0663	9.38	0.472	0.621	1295	11.1	M6,9450-3401	10.3	0.654	0.553	1021	12.6
M4,1579-0663	9.11	0.350	0.644	1427	10.4	M6,9475-3415	9.84	0.595	0.457	896	11.9

## Appendix. (continued).

Spot No.	ThO <sub>2</sub> (wt %)	UO <sub>2</sub> (wt %)	PbO (wt %)	Age (Ma)	UO <sub>2</sub> * ThO <sub>2</sub> *	Spot No.	ThO <sub>2</sub> (wt %)	UO <sub>2</sub> (wt %)	PbO (wt %)	Age (Ma)	UO <sub>2</sub> * ThO <sub>2</sub> *
M6,9463-3415	8.78	0.516	0.384	850	10.5	Sample EG99012268					
M6,9451-3415	9.71	0.569	0.435	870	11.6	Zircon					
M6,9437-3415	10.2	0.634	0.469	884	12.4	Z01	0.003	0.269	0.103	2222	0.270
M6,9422-3422	10.1	0.637	0.554	1048	12.3	Z01	0.007	0.162	0.0541	1987	0.164
M6,9434-3436	10.2	0.623	0.554	1039	12.4	Z01	0.004	0.259	0.0971	2179	0.260
M6,9449-3436	10.2	0.605	0.476	901	12.3	Z01	0.010	0.168	0.0596	2075	0.170
M6,9462-3436	10.3	0.642	0.509	947	12.5	Z01	0.014	0.041	0.0168	2188	0.045
M6,9475-3436	10.2	0.634	0.501	941	12.4	Z01	0.020	0.036	0.0150	2150	0.041
M6,9521-3327	10.0	0.649	0.463	882	12.2	Z01	0.003	0.205	0.0824	2297	0.206
M6,9510-3330	8.88	0.622	0.385	817	11.0	Z01	0.020	0.161	0.0644	2245	0.166
M6,9377-3323	10.0	0.606	0.493	945	12.1	Z01	0.004	0.099	0.0341	2041	0.100
M6,9321-3300	9.67	0.574	0.593	1174	11.7	Z01	0.007	0.275	0.111	2304	0.276
M6,9215-3114	6.86	0.649	0.286	740	9.04	Z01	0.008	0.280	0.111	2266	0.282
M6,9215-3128	8.84	0.671	0.448	936	11.1	Z01	0.013	0.035	0.0126	1972	0.038
M6,9190-3128	9.63	0.564	0.470	945	11.6	Z01	0.012	0.219	0.0889	2293	0.223
M6,9208-3143	10.0	0.673	0.481	907	12.3	Z01	0.007	0.155	0.0583	2175	0.157
M6,9167-3143	8.19	0.674	0.411	911	10.5	Z01	0.006	0.205	0.0817	2274	0.207
M6,9193-3158	9.71	0.437	0.528	1089	11.2	Z01	0.005	0.250	0.0924	2158	0.251
M6,9173-3158	10.1	0.460	0.421	844	11.6	Z01	0.006	0.246	0.0998	2313	0.247
M6,9145-3158	9.18	0.903	0.586	1102	12.3	Z01	0.014	0.241	0.0964	2269	0.245
M6,9185-3176	9.37	0.416	0.491	1053	10.8	Z01	0.007	0.215	0.0808	2181	0.216
M6,9167-3176	9.64	0.440	0.443	924	11.1	Z01	0.006	0.269	0.109	2304	0.270
M6,9153-3176	9.47	0.775	0.417	805	12.1	Z01	0.004	0.216	0.0757	2073	0.217
M6,9162-3186	9.93	0.661	0.457	873	12.2	Z01	0.006	0.079	0.0316	2262	0.081
M6,9076-3090	8.89	0.686	0.388	807	11.2	Z01	0.004	0.266	0.0859	1943	0.267
M6,9059-3090	9.37	0.732	0.450	883	11.9	Z01	0.008	0.272	0.102	2178	0.274
M6,9019-3090	9.48	0.626	0.448	897	11.6	Z01	0.005	0.256	0.0984	2223	0.257
M6,8997-3090	10.3	0.627	0.385	725	12.4	Z01	0.005	0.261	0.0839	1938	0.262
M6,9015-3110	9.18	0.643	0.382	785	11.4	Z01	0.005	0.073	0.0286	2239	0.074
M6,8997-3071	10.2	0.627	0.463	874	12.3	Z01	0.006	0.259	0.100	2226	0.261
M6,9018-3071	10.7	0.623	0.504	917	12.8	Z01	0.005	0.224	0.0825	2146	0.226
M6,9066-3071	9.56	0.709	0.418	815	12.0	Z01	0.005	0.197	0.0789	2283	0.199
M6,9031-3041	10.0	0.701	0.422	794	12.4	Z01	0.005	0.246	0.0924	2180	0.247
M6,9003-3041	8.95	0.678	0.388	804	11.2	Z01	0.004	0.148	0.0574	2228	0.149
M6,8976-3041	8.67	0.655	0.352	756	10.9	Z02	0.003	0.105	0.0351	1990	0.106
M6,9000-3013	9.07	0.758	0.366	735	11.6	Z02	0.016	0.037	0.0160	2249	0.041
M6,8975-3013	9.48	0.700	0.396	780	11.8	Z02	0.017	0.051	0.0191	2063	0.055
M6,8953-2979	8.87	0.675	0.360	754	11.1	Z02	0.020	0.050	0.0170	1886	0.055
M6,8831-2916	8.51	0.616	0.298	659	10.6	Z02	0.013	0.044	0.0206	2460	0.047
M6,8792-2916	10.4	0.641	0.411	762	12.6	Z02	0.018	0.047	0.0180	2085	0.051
M6,8847-2943	8.21	0.616	0.276	630	10.3	Z02	0.009	0.052	0.0208	2218	0.054
M6,8680-2933	9.83	0.715	0.427	813	12.3	Z02	0.018	0.047	0.0199	2226	0.052
M6,8617-2902	9.06	0.542	0.364	780	10.9	Z02	0.016	0.047	0.0204	2308	0.051
M6,8751-2902	10.6	0.674	0.466	841	12.9	Z02	0.011	0.050	0.0187	2091	0.053
M6,8790-2902	8.65	0.635	0.419	901	10.8	Z02	0.007	0.049	0.0184	2131	0.051
M6,8815-2902	7.94	0.619	0.315	734	10.0	Z02	0.012	0.052	0.0167	1859	0.055
M6,8783-2872	9.93	0.621	0.546	1049	12.1	Z02	0.011	0.060	0.0210	2013	0.062
M6,8739-2872	9.98	0.626	0.439	845	12.1	Z02	0.015	0.056	0.0241	2316	0.060
M6,8705-2872	9.17	0.589	0.381	796	11.2	Z02	0.017	0.039	0.0135	1912	0.043
M6,8592-2899	8.93	0.536	0.276	604	10.7	Z02	0.017	0.053	0.0184	1944	0.057
M6,8690-2841	8.50	0.623	0.322	711	10.6	Z02	0.014	0.036	0.0171	2439	0.039
M6,8645-2836	8.62	0.622	0.291	636	10.7	Z02	0.010	0.056	0.0210	2126	0.058
M6,8601-2836	8.75	0.524	0.273	610	10.5	Z02	0.010	0.051	0.0202	2204	0.053
M6,8574-2802	8.79	0.497	0.285	639	10.5	Z02	0.013	0.046	0.0172	2066	0.049
M6,8568-2815	8.97	0.508	0.282	619	10.7	Sample GE99012234 (not used)					
M6,8558-2804	9.17	0.506	0.275	594	10.9	Z01-01	0.017	0.035	0.0113	1777	0.039
M6,8496-2861	8.84	0.510	0.336	743	10.6	Z01-02	0.018	0.032	0.0029	559	0.037
M6,8383-2749	8.20	0.501	0.259	616	9.87	Z01-03	0.016	0.033	0.0045	831	0.038
M6,8706-2870	8.63	0.577	0.339	750	10.6	Z01-04	0.018	0.031	0.0063	1173	0.036
M6,8774-2882	10.0	0.576	0.538	1040	12.0	Z01-05	0.020	0.028	0.0072	1394	0.034
M6,8818-2917	9.05	0.628	0.338	708	11.2	Z02-06	0.015	0.029	0.0074	1442	0.033
M6,8791-2895	9.39	0.609	0.483	977	11.5						

*Appendix. (continued).*

Spot No.	ThO <sub>2</sub> (wt %)	UO <sub>2</sub> (wt %)	PbO (wt %)	Age (Ma)	UO <sub>2</sub> * ThO <sub>2</sub> *
Z01-07	0.019	0.028	0.0055	1117	0.033
Z01-08	0.023	0.031	0.0086	1497	0.037
Z01-09	0.020	0.033	0.0044	785	0.039
Z01-10	0.021	0.035	0.0083	1335	0.041
Z01-11	0.016	0.029	0.0082	1571	0.033
Z01-12	0.017	0.027	0.0070	1412	0.032
Z01-13	0.017	0.032	0.0046	864	0.037
Z01-14	0.020	0.027	0.0056	1148	0.033
Z01-15	0.015	0.031	0.0045	880	0.035
Z01-16	0.021	0.035	0.0062	1019	0.041
Z01-17	0.021	0.036	0.0073	1173	0.042
Z01-18	0.018	0.033	0.0053	956	0.038
Z01-19	0.019	0.026	0.0080	1607	0.031
Z01-20	0.019	0.028	0.0067	1305	0.034
Z01-21	0.020	0.025	0.0066	1395	0.031
Z01-22	0.012	0.028	0.0048	1045	0.031
Z01-23	0.023	0.033	0.0085	1397	0.039
Z01-24	0.022	0.035	0.0053	882	0.041
Z01-25	0.017	0.028	0.0064	1285	0.033
Z01-26	0.020	0.033	0.0048	863	0.038
Z01-27	0.021	0.034	0.0086	1405	0.040
Z01-28	0.017	0.028	0.0054	1112	0.033
Z02-01	0.013	0.029	0.0035	734	0.033
Z02-02	0.016	0.031	0.0052	1004	0.035
Z02-03	0.016	0.026	0.0052	1143	0.030
Z02-04	0.014	0.027	0.0049	1084	0.030
Z02-05	0.013	0.027	0.0036	800	0.031
Z02-06	0.012	0.030	0.0060	1185	0.034
Z02-07	0.012	0.028	0.0030	666	0.032
Z02-08	0.013	0.027	0.0041	910	0.031
Z02-09	0.013	0.029	0.0062	1268	0.032
Z02-10	0.015	0.031	0.0071	1326	0.035
Z02-11	0.013	0.026	0.0061	1343	0.030
Z02-12	0.014	0.027	0.0038	842	0.031
Z02-13	0.024	0.038	0.0068	1030	0.045
Z03-01	0.007	0.026	0.0065	1478	0.028
Z03-02	0.010	0.026	0.0067	1501	0.029
Z03-03	0.004	0.035	0.0077	1382	0.036
Z03-04	0.015	0.027	0.0082	1642	0.031
Z04-01	0.016	0.029	0.0083	1570	0.034
Z04-02	0.020	0.031	0.0047	882	0.037

## Note

UO<sub>2</sub>\*: sum of the measured UO<sub>2</sub> and UO<sub>2</sub>  
equivalent of the measured ThO<sub>2</sub> for xenotime  
and zircon.

ThO<sub>2</sub>\*: sum of the measured ThO<sub>2</sub> and ThO<sub>2</sub>  
equivalent of the measured UO<sub>2</sub> for monazite.

Analyzed position is shown for some grain in  
 $\mu$  m: e.g. X01,0092-2219 means 92  $\mu$  m  
from right and 2219  $\mu$  m from top.