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Appendix DR1. Tables DR1–DR10, Figure DR1-DR11, SHRIMP procedures and data.

Isotopic Dating of the Migration of a Low-Grade Metamorphic Front during Orogenesis

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SHRIMP Analytical Procedures

Data for this paper were collected over four years. There were no changes in the basic data acquisition procedures during this period, though some of the data were acquired using a newer SHRIMP. Monazite analytical procedures followed established methodologies (Foster et al., 2000; Rasmussen et al., 2001), while xenotime procedures are described in (Fletcher et al., 2000). Analysis areas were typically ~10 μm, with a primary O_2^- ion current ~1 nA, but smaller spots (with correspondingly lower beam currents) were required in some cases.

Additional calibration standards became available early in the project and thereafter better control was possible for the corrections made for matrix effects on element-ratio measurements. The primary standard used for monazite was MAD 1 (Foster et al., 2000; also known in-house as French) except for one early data set that used MPN. For the majority of data sets, matrix effects were determined using PD-95 (high U; Th generally higher than MAD; provided by J. Aleinikoff) and QMa28-1 (U similar to MAD, but with lower Th; provided by F. Henjes-Kunst). For xenotime, the standards were MG-1, BS-1 and z6413 (Fletcher et al., 2004). PD-95 and z6413 also provide monitors for $^{207}Pb/^{206}Pb$. Typically, each analytical session included 6–8 analyses of both the primary standard and the $^{207}Pb/^{206}Pb$ monitor and 2–3 analyses of the other secondary standard.

For several early monazite data sets only the primary standard was analysed sufficiently, and matrix corrections were applied using previously determined parameters (Rasmussen et al., 2002) with data reduced using fixed calibration slopes. For most monazite data sets, both the calibration slopes and the matrix corrections were determined internally, using the secondary standards with varying U and Th abundances to quantify the matrix effects. It is assumed that light rare earth element (REE) substitutions in monazite generally have no significant effect on measured element ratios but there is one extreme case (Sample 1) where the possibility is discussed below. For xenotime, the Th abundances are modest in all samples and the only matrix corrections applied were based on U differences and the REE difference between MG-1 and typical hydrothermal xenotime. Calibration slope, U abundances and matrix correction factors were determined within each data set.

Data assessments

Concordance

One of the principal discriminants for assessing U–Pb data is concordance. For example, in dealing with mid-Proterozoic SHRIMP data for zircon it would be normal to disregard data that are >5% discordant, since it can reasonably be assumed that samples yielding such data have suffered significant Pb loss. With the data presented here, such a strict numerical criterion cannot be applied because there are several ways that discordant data can result from analyses of concordant samples. These problems all relate to perturbations of Pb/U calibrations.

One underlying limitation arises from having the samples on a different mount than the calibration standards. This is compounded by the fact that the samples are fragments of polished sections, whereas the standards are small grains or crystal fragments, so there are unavoidable (though minor) topographic differences. Although the two mounts were cleaned and Au-coated together, Pb/U calibration differences between mounts can be up to ~1% and perhaps, on occasion, ~2%. Experience over several years indicates that it is generally <2%, but cannot be quantified directly for any individual data set. There is no way of eliminating this effect without mounting additional standards with the samples and collecting additional data. This is impractical in terms of the supply of standard material and/or analysis time.

In some cases where sample material was limited, analysis spots were placed adjacent to each other. Such close spacing can affect Pb^+/UO_n^+ response. In some cases where the grains were small, the primary ion beam was moved across the sample surface to optimise the analysis location. This modifies the shape of the zone stripped of Au by beam rastering and also varies the time-base for the analysis; both of these can affect the Pb/U calibration.

In many cases, data were collected for sequential analyses on a single location. When this is done, there is a significant drift in Pb/U calibration between the sequential analyses – typically ~5% for small-spot analyses of xenotime (Fletcher et al., 2000), but smaller for most of the monazite analyses presented here. Although it is possible to calibrate the time-drift with additional (sequential) analyses of the standard(s), this was considered unjustified for this project because of the cost in sample analytical time. Sequential analyses have been assessed on the basis of typical drift rates and the concordance of the corresponding first analyses, which represent immediately adjacent sample material.

Matrix effects on measured Pb/U are well known and these data have been matrix-corrected. However, the corrections, as well as the primary calibration, are made on the basis of minimal data sets. Therefore, the precision of the corrections is not well determined, but could be in the percent range, and no attempt is made to propagate this uncertainty. In principle, this situation could be improved by collecting larger data sets for the standards, but this must be balanced against the time available for sample analyses. Overall, we consider it likely that concordant samples can have generated data with apparent discordance of up to ~10%. Depending on data availability, we have made assessments under both rigorous (±5%) and more inclusive (±~10%) concordance criteria. In many respects, these comments also apply to the Pb/Th data in the one case where these were used to supplement U–Pb data.

Accuracy limit

There are systematic limits to the accuracy of $^{207}Pb/^{206}Pb$ dates determined from data acquired in a single analytical session. There are two main reasons for this. Firstly, the data are corrected for common Pb on the basis of recorded ^{204}Pb. While this is fundamentally sound practice, there is a problem in the case of monazite because of an isobaric interference on ^{204}Pb. The magnitude of the interference correlates strongly with Th abundance (Foster et al., 2000) and the measured mass-204 signal is corrected by reference to the observed mass-204 and Th signals for the MAD standard. Since the same MAD data are used with all sample data in a session, any error in the isobar correction is not detectable in the processed data. Such errors are small, but are not quantifiable. Secondly, when operating SHRIMP with the retardation lens activated, it is common to observe fractionation in $^{207}Pb/^{206}Pb$. Here again, corrections are made, so final errors should be small. Also, when no statistically significant offset is observed in the standard data, no correction is applied, even though there may be a small fractionation.

In consideration of these limitations, we apply a minimum ± 10 Ma uncertainty to any $^{207}Pb/^{206}Pb$ age determined wholly from data from a single analytical session. This limitation is reduced when data from multiple sessions are used, since the effects are largely random between sessions. These limitations were not fully appreciated in earlier projects, and similar limits were not applied to previously published data (e.g., Rasmussen et al., 2001).

Data presentation

Data are compiled below for each sample.

In the tables, the analyses are identified as NNNNA.p-qx, where
NNNN is the mount number; *A* in the fragment of polished thin section in mount NNNN; *p* is the grain within fragment A; *q* is the analysis area in grain p; and *x* (a, b or c) is the sequential analysis at site p. This is omitted in tables where only single analyses were recorded.

For monazite, U and Th abundances are determined relative to the homogeneous MAD standard from raw UO_2^+/ $CePO_2^+$ and $ThO_2^+/CePO_2^+$ data. For xenotime, they are determined from averaged data for MG-1 and z6413 using UO^+/Y_2O^+ and a fixed Th/U calibration. The U and Th concentrations are considered accurate to ±~20%. Th/U is more accurate than the separate abundances.

All tabulated Pb data are corrected for common Pb on the basis of measured ^{204}Pb, assuming a common Pb composition equivalent to Broken Hill galena. Any differences between this assumed composition and the actual common Pb composition are almost certainly insignificant for the data used to define ages. The magnitude of the common-Pb correction is listed as 4f206, the proportion of ^{206}Pb determined to be common Pb.

The U–Pb concordance (“conc.”, as percent) is defined as $100\{t[^{206}Pb/^{238}U]/t[^{207}Pb/^{206}Pb]\}$.

Data are listed and plotted with 1σ uncertainties that apply to the last digits listed. These include sources of random error such as counting statistics and primary ion beam noise, propagated through data reduction, but do not include uncertainties in systematic factors such as matrix correction parameters. Where ^{207}Pb/^{206}Pb renormalisation was required, the corresponding uncertainty was applied to the ^{207}Pb/^{206}Pb data for individual analyses. The data for second and third analyses in single locations, although not fully calibrated (see above), are listed for completeness and identified by italic font in reduced size.

The Concordia plots show only data from first analyses, since there is no way to make a formal correction to the Pb/U for subsequent sequential analyses. The main data subset used for weighted mean ages is shown unshaded. Data of questionable significance are shaded. In some cases there are poorer-quality data that fall outside the plotted field.

Sample 1

Sample details

This sample comprises shale from the Jeerinah Formation intersected in drill-hole RHDH2A (Fig. 1). The shale contains minute monazite crystals, but only in three samples are grains sufficiently large (>15 μm) for SHRIMP analysis (between 267.0 m and 268.6 m).

Analytical notes

Data were acquired in three analytical sessions from three mounts. The first session was very early in the project (July 2000) and data were calibrated against the in-house standard MPN only. MPN also provides a $^{207}Pb/^{206}Pb$ monitor, though it is not highly precise for this purpose.

The samples have low U (mostly <100 ppm) and highly variable Th. They also have highly unusual REE contents. The recorded $CePO_2^+$ secondary ion beam strengths are about half that recorded for the standards; although some variability is common, this is several times greater than observed elsewhere. The diminution in Ce cannot readily be explained by dilution of Ce by other light REE, since the recorded $LaPO_2^+$ is also lower, at ~20% of typical levels. The variant composition appears to have had no significant effect on apparent concordance.

Despite the low U abundances, most data are of reasonable quality, with only about 30% of analyses having >1% common Pb or >10% apparent discordance. The remaining 28 analyses give a weighted mean $^{207}Pb/^{206}Pb$ age of 2145.9 ± 9.3 Ma (MSWD = 0.96). If the selection is restricted data to within 5% of apparent concordance, this actually degrades slightly to 2143 ± 12 Ma (MSWD = 0.88).

Interpretation

The only identifiable age for monazite growth is 2146 ± 10 Ma. This sample has highly unusual minor-element composition.

Date

The age of monazite growth is 2146 ± 10 Ma.

TABLE DR1. SHRIMP DATA FOR MONAZITE IN SAMPLE 1, RHDH2A

Analysis	U (ppm)	Th (ppm)	Th/U	f206 (%)	$^{207}Pb^*/^{206}Pb^*$	±	$^{206}Pb^*/^{238}U$	±	$^{207}Pb^*/^{235}U$	±	$^{208}Pb^*/^{232}Th$	±	conc. (%)	$^{207}Pb^*/^{206}Pb^*$ Age (Ma)	±	Date
Main group																
0473G.1-3a	30	852	28.6	0.998	0.1269	59	0.4168	206	7.291	523	0.1192	43	109	2055	83	16-Jul-04
03101E.1-1a	58	1327	22.8	0.389	0.1301	22	0.4090	136	7.335	284	0.1211	20	105	2099	30	13-Dec-03
A21A.1-2b	*56*	*705*	*12.5*	0.362	0.1312	18	*0.3492*	*82*	*6.317*	*182*	*0.1176*	*32*	*91*	2114	25	20-Jul-00
0473F.1-3a	73	440	6.0	0.764	0.1313	54	0.3977	187	7.202	476	0.1179	55	102	2116	72	16-Jul-04
A21A.2-1b	*56*	*278*	*5.0*	0.250	0.1315	17	*0.3647*	*86*	*6.612*	*185*	*0.1103*	*37*	*95*	2118	22	20-Jul-00
A21A.1-1a	136	928	6.8	0.347	0.1316	17	0.3795	117	6.885	238	0.1077	22	98	2119	23	13-Dec-03
A21A.2-1c	*51*	*300*	*5.9*	0.000	0.1321	13	*0.3560*	*86*	*6.485*	*176*	*0.1120*	*36*	*92*	2126	17	20-Jul-00
A21A.1-1a	92	265	2.9	0.195	0.1321	12	0.3879	85	7.065	174	0.1107	37	99	2126	16	20-Jul-00
0473E.1-1b	*113*	*31*	*0.3*	0.390	0.1322	31	0.3764	131	6.860	305	0.0798	155	97	2127	42	16-Jul-04
A21A.1-1b	*88*	*277*	*3.2*	0.212	0.1328	13	*0.3712*	*80*	*6.796*	*169*	*0.1141*	*37*	*95*	2135	18	20-Jul-00
A21A.1-2a	69	537	7.7	0.136	0.1333	14	0.3734	84	6.864	178	0.1204	35	95	2142	18	20-Jul-00
0473F.1-1a	66	203	3.1	0.195	0.1334	44	0.4014	161	7.385	405	0.1200	66	101	2144	58	16-Jul-04
A21A.1-1b	*128*	*1003*	*7.8*	0.000	0.1337	14	*0.3710*	*117*	*6.839*	*234*	*0.1060*	*20*	*95*	2147	18	13-Dec-03
0473F.1-2a	71	173	2.4	0.000	0.1338	26	0.4242	173	7.823	372	0.1119	68	106	2148	34	16-Jul-04
0473K.1-1a	62	219	3.6	0.286	0.1341	32	0.3946	130	7.293	313	0.1162	52	100	2152	42	16-Jul-04
A21A.1-1c	*84*	*293*	*3.5*	0.106	0.1344	13	*0.3570*	*78*	*6.617*	*164*	*0.1174*	*37*	*91*	2156	17	20-Jul-00
0473D.1-3a	86	415	4.8	0.000	0.1345	21	0.4188	139	7.766	298	0.1183	50	105	2158	27	16-Jul-04
A21A.3-1b	*59*	*276*	*4.6*	0.363	0.1349	18	*0.3441*	*81*	*6.399*	*182*	*0.0988*	*42*	*88*	2162	23	20-Jul-00
A21A.2-1a	58	265	4.6	0.239	0.1348	16	0.3809	90	7.081	195	0.1095	37	96	2162	21	20-Jul-00
A21A.3-1a	67	149	2.2	0.124	0.1352	17	0.3780	86	7.049	193	0.1110	49	95	2167	22	20-Jul-00
0473E.1-2b	*43*	*270*	*6.3*	0.000	0.1355	39	*0.3486*	*182*	*6.514*	*408*	*0.1032*	*51*	*89*	2171	50	16-Jul-04
A21A.1-2a	104	733	7.1	0.000	0.1356	16	0.3889	125	7.271	257	0.1044	21	97	2172	21	13-Dec-03
0473K.2-4a	21	564	27.2	0.596	0.1357	75	0.4138	241	7.743	654	0.1218	47	103	2173	96	16-Jul-04
A21A.1-2b	67	738	11.0	0.116	0.1359	25	*0.3531*	*125*	*6.615*	*274*	*0.1008*	*21*	*90*	2176	32	13-Dec-03
A21A.3-1b	*61*	*390*	*6.4*	0.173	0.1364	24	*0.3760*	*124*	*7.070*	*274*	*0.1014*	*48*	*94*	2182	30	13-Dec-03
03101E.1-1b	*78*	*1269*	*16.3*	0.000	0.1366	17	*0.3638*	*123*	*6.855*	*255*	*0.1122*	*20*	*92*	2185	22	13-Dec-03
0473K.2-2a	36	4218	116.4	0.294	0.1399	47	0.3924	160	7.570	424	0.1160	36	96	2226	59	16-Jul-04
0473G.1-4a	41	274	6.6	0.837	0.1431	66	0.4330	201	8.546	588	0.1161	53	102	2266	79	16-Jul-04
>10% apparent discordance																
A21A.2-1b	*77*	*419*	*5.4*	0.011	0.1381	26	*0.2960*	*112*	*5.636*	*247*	*0.0841*	*30*	*76*	2203	32	13-Dec-03
A21A.3-1c	*48*	*380*	*8.0*	0.054	0.1488	19	*0.3168*	*79*	*6.502*	*190*	*0.0940*	*33*	*76*	2333	22	20-Jul-00
A21A.3-1a	113	272	2.4	0.000	0.1275	34	0.3046	134	5.354	286	0.0825	35	83	2064	47	13-Dec-03
A21A.2-1a	60	306	5.1	0.000	0.1359	21	0.3523	127	6.599	267	0.1002	39	89	2175	27	13-Dec-03
0473D.1-2a	30	241	8.1	0.940	0.1266	81	0.4338	227	7.574	656	0.1147	62	113	2052	113	16-Jul-04

>1% common Pb																
0473D.1-1a	34	192	5.6	1.369	0.1314	76	0.3806	215	6.898	587	0.1063	62	98	2117	101	16-Jul-04
0473K.2-1a	33	2353	72.2	1.574	0.1187	64	0.4028	170	6.593	472	0.1153	37	113	1937	96	16-Jul-04
A21A.1-3a	51	885	17.5	2.158	0.1321	32	0.3892	105	7.091	272	0.1114	30	100	2126	43	20-Jul-00
0473K.3-1a	29	2115	74.0	2.223	0.1230	115	0.3657	255	6.203	755	0.1152	40	100	2000	166	16-Jul-04
0473K.2-3a	27	1692	63.2	3.588	0.1360	107	0.4059	191	7.609	724	0.1144	37	101	2176	137	16-Jul-04
0473G.2-1a	26	1554	60.2	4.052	0.1190	128	0.4191	244	6.875	870	0.1164	40	116	1941	192	16-Jul-04
0473K.3-2a	43	5586	130.9	4.751	0.1445	137	0.3865	220	7.701	884	0.1144	37	92	2282	163	16-Jul-04

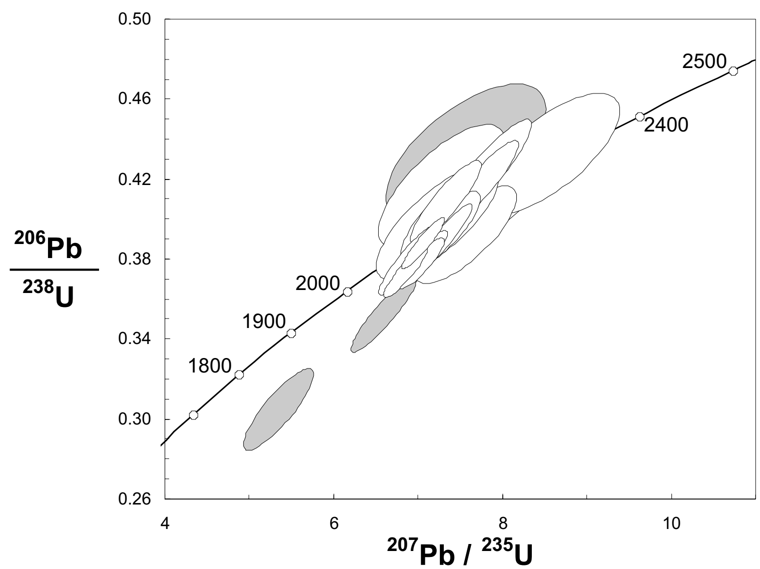

Fig. DR1. SHRIMP U–Pb data for monazite from Sample 1, RHDH2A. Shaded points have <1% common Pb, but >10% apparent discordance.

Sample 2

Sample details

Sample 2 is a black shale belonging to the mid-Archaean Gorge Creek Group intersected in drill-hole KCD-22 (Fig. 1) at a depth of 114. 2 m. Monazite crystals are common in this sample where they occur as thin, bedding-parallel aggregates up to 500 μm long.

Analytical notes

The data are almost all from one large grain, with two analyses from a second grain. A large portion of the data was collected in one analytical session, with some supplementary analyses in other sessions.

Interpretation

The ^{207}Pb/^{206}Pb clearly form a single population. Averaging all data with <2% common ^{206}Pb gives a weighted mean ^{207}Pb/^{206}Pb age of 2154.6 ± 9.8 Ma (*n* = 15; MSWD = 0.66). Applying more stringent criteria for data selection, such as restricting 4f206 to <1%, makes no difference to this result.

Date

The age of monazite growth is 2155 ± 10 Ma.

TABLE DR2. SHRIMP DATA FOR MONAZITE IN SAMPLE 2, KCD-22

Analysis	U (ppm)	Th (ppm)	Th/U	f206 (%)	$^{207}Pb^*/^{206}Pb^*$	±	$^{206}Pb^*/^{238}U$	±	$^{207}Pb^*/^{235}U$	±	$^{208}Pb^*/^{232}Th$	±	conc. (%)	$^{207}Pb^*/^{206}Pb^*$ Age (Ma)	±	Date
Main data set, in order of $^{207}Pb/^{206}Pb$ age																
A86E.1-11a	795	3320	4.17	1.157	0.1317	23	0.3864	141	7.017	298	0.1030	31	99	2121	30	16-Jul-02
A86E.1-3a	515	1564	3.04	0.580	0.1322	18	0.3881	142	7.076	290	0.1025	37	99	2128	24	16-Jul-02
A86E.1-12a	943	1002	1.06	0.118	0.1332	11	0.4190	147	7.696	286	0.1138	48	105	2141	15	16-Jul-02
A86E.1-6b	982	4275	4.35	0.457	0.1335	15	0.4047	143	7.450	287	0.1106	30	102	2145	19	16-Jul-02
A86E.1-4b	*887*	*755*	*0.85*	0.838	0.1336	18	*0.4039*	*142*	*7.439*	*295*	*0.1079*	*51*	*102*	2146	24	16-Jul-02
A86E.1-5a	740	3043	4.11	1.052	0.1338	21	0.4014	145	7.404	308	0.1057	33	101	2148	28	16-Jul-02
A86E.1-12b	*918*	*1104*	*1.20*	0.077	0.1338	13	*0.4343*	*159*	*8.014*	*315*	*0.1165*	*52*	*108*	2149	17	16-Jul-02
A86E.2-1a	437	2515	5.76	0.131	0.1342	12	0.4053	40	7.498	104	0.1137	38	102	2153	15	20-Apr-02
A86E.1-6a	1009	4617	4.58	0.245	0.1343	13	0.4140	146	7.669	291	0.1102	30	104	2155	17	16-Jul-02
A86E.1-2b	*938*	*2510*	*2.68*	0.429	0.1347	9	*0.3838*	*105*	*7.125*	*206*	*0.1078*	*19*	*97*	2159	12	13-Dec-03
A86E.1-1a	820	1813	2.21	0.649	0.1346	15	0.3876	40	7.196	116	0.1062	35	98	2159	20	20-Apr-02
A86E.1-10a	666	2316	3.48	1.055	0.1348	20	0.4062	145	7.550	308	0.1018	31	102	2161	26	16-Jul-02
A86E.1-13a	574	1682	2.93	1.968	0.1349	27	0.3846	138	7.153	312	0.0946	30	97	2163	35	16-Jul-02
A86E.1-4a	978	809	0.83	0.526	0.1354	18	0.3986	140	7.441	294	0.1143	55	100	2169	24	16-Jul-02
A86E.2-2a	563	996	1.77	0.188	0.1370	13	0.3895	39	7.356	105	0.1123	40	97	2189	16	20-Apr-02
Not used (high common Pb)																
A86E.1-8a	623	2108	3.38	2.067	0.1309	30	0.3929	143	7.093	322	0.0958	29	101	2110	40	16-Jul-02
A86E.1-7a	587	3218	5.48	2.130	0.1321	30	0.3870	140	7.047	319	0.0982	27	99	2126	40	16-Jul-02
A86E.1-9a	545	3302	6.06	4.122	0.1257	41	0.3853	141	6.675	348	0.0953	26	103	2038	57	16-Jul-02
A86E.1-3b	*421*	*3689*	*8.76*	4.195	0.1247	50	*0.3637*	*140*	*6.254*	*369*	*0.0957*	*26*	*99*	2025	71	16-Jul-02
A86E.1-15a	528	2370	4.48	4.927	0.1328	47	0.3672	135	6.722	367	0.0870	26	94	2135	62	16-Jul-02
A86E.1-14a	619	3067	4.95	10.430	0.1188	118	0.3832	147	6.278	696	0.0991	36	108	1939	177	16-Jul-02

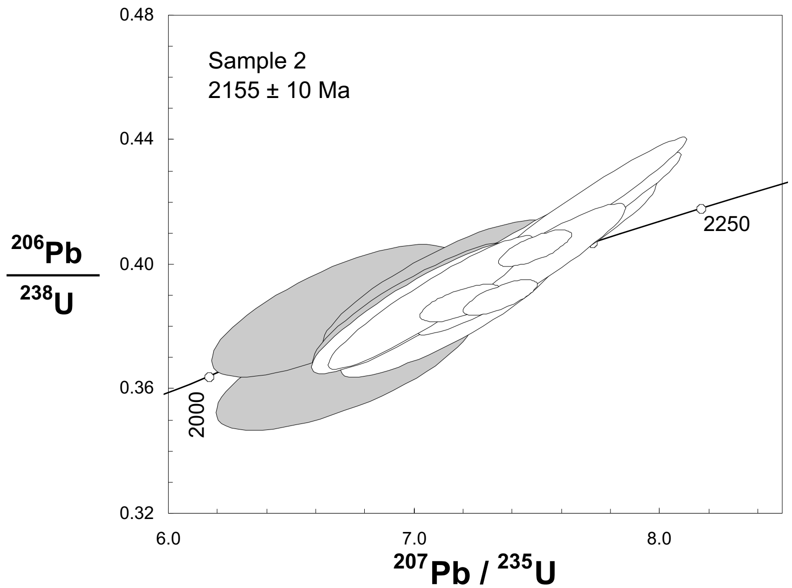

Fig. DR2. SHRIMP U–Pb data for monazite from Sample 2, KCD-22. One analysis with high common Pb is not plotted.

Sample 3

Sample details

Sample 3 consists of sandstone from the Hardey Formation of the Fortescue Group intersected in drill-hole BD-2 (Fig. 1). Monazite occurs as coarse, matrix-filling cement.

Analytical notes

Data are mostly from a single analytical session, with several supplementary analyses from a separate session.

Interpretation

The main data group, incorporating about two-thirds of the data, is from two grains and defines a single age population. One analysis from one of these grains has distinctly low Th (essentially zero) and two from a third grain have much lower U and higher Th, but these all fit into the same $^{207}Pb/^{206}Pb$ population as the majority data set, as would the data excluded on the grounds of discordance or high common Pb.

All data with <2% common Pb and within 10% of apparent concordance give a weighted mean $^{207}Pb/^{206}Pb$ age of 2175.5 ± 7.0 Ma (n = 18; MSWD = 1.5). More severe data restrictions make no significant difference. For example, using only data with 4f206 < 1% and discordance <5% gives 2173.3 ± 6.1 Ma (n = 13; MSWD = 1.08).

Date

The age of monazite growth is 2175 ± 10 Ma. The ± 10 Ma uncertainty is applied because all data contributing to the averaged age are from a single analytical session (see above).

TABLE DR3. SHRIMP DATA FOR MONAZITE IN SAMPLE 3, BD-2

Analysis	U (ppm)	Th (ppm)	Th/U	f206 (%)	^{207}Pb*/ ^{206}Pb*	±	^{206}Pb*/ ^{238}U	±	^{207}Pb*/ ^{235}U	±	^{208}Pb*/ ^{232}Th	±	conc. (%)	^{207}Pb*/^{206}Pb* Age (Ma)	±	Date
Main data set, in order of ^{207}Pb/^{206}Pb																
C101E.1-6	195	387	1.99	0.284	0.1340	9	0.4132	88	7.633	175	0.1117	32	104	2151	12	11-Feb-03
C101D.10-1	308	250	0.81	0.931	0.1341	12	0.4313	91	7.974	187	0.1166	40	107	2152	15	11-Feb-03
C101D.1-3	366	324	0.88	1.285	0.1345	14	0.3754	79	6.960	169	0.1142	43	95	2157	18	11-Feb-03
C101E.1-2	558	453	0.81	0.388	0.1349	7	0.3985	81	7.412	158	0.1073	30	100	2163	9	11-Feb-03
C101E.1-7	678	457	0.67	0.582	0.1354	7	0.3918	79	7.313	155	0.1051	31	98	2169	9	11-Feb-03
C101D.1-18	148	1750	11.85	0.234	0.1354	10	0.4124	92	7.700	184	0.1193	28	103	2170	12	11-Feb-03
C101E.1-1	470	1633	3.47	0.150	0.1355	8	0.3801	80	7.101	159	0.1101	28	96	2170	10	11-Feb-03
C101E.1-5	448	381	0.85	0.077	0.1360	7	0.4328	89	8.115	175	0.1172	33	107	2177	9	11-Feb-03
C101D.1-16	202	100	0.50	0.422	0.1360	10	0.4044	88	7.584	179	0.1156	50	101	2177	13	11-Feb-03
C101D.1-15	392	1197	3.05	0.204	0.1368	7	0.4032	83	7.607	165	0.1146	28	100	2188	9	11-Feb-03
C101D.12-1	299	1102	3.69	0.240	0.1369	7	0.4366	90	8.240	178	0.1184	30	107	2188	8	11-Feb-03
C101D.1-2	93	138	1.48	0.964	0.1372	25	0.4063	95	7.685	237	0.1214	50	100	2192	32	11-Feb-03
C101D.13-1	257	1089	4.23	0.516	0.1375	11	0.3927	82	7.444	172	0.1175	29	97	2195	14	11-Feb-03
C101D.1-7	351	699	1.99	0.857	0.1380	11	0.3719	80	7.076	168	0.0978	28	93	2203	14	11-Feb-03
C101D.1-6	338	451	1.33	1.467	0.1383	17	0.3673	85	7.003	191	0.1057	30	91	2206	21	11-Feb-03
Main age-group but unusual composition																
0377J.1-2	20	9340	466	0.744	0.1296	47	0.3903	178	6.971	428	0.1133	26	102	2092	64	21-Jan-04
0377J.1-1	17	6505	385	0.240	0.1369	31	0.4084	191	7.710	419	0.1153	23	101	2189	40	21-Jan-04
C101E.1-4	511	0	0.00	0.010	0.1358	7	0.4150	85	7.774	168	0.1429	846	103	2175	9	11-Feb-03
Data not used (discordant or high common Pb)																
C101D.1-8	124	361	2.91	0.868	0.1414	31	0.3257	95	6.350	241	0.0963	39	81	2244	38	11-Feb-03
C101D.1-4	405	676	1.67	2.801	0.1383	21	0.3937	86	7.507	207	0.1124	32	97	2206	26	11-Feb-03
0377K.1-2	29	7203	245	3.645	0.1355	62	0.6040	367	11.283	901	0.1187	27	140	2170	80	21-Jan-04
C101D.1-17	131	1179	9.02	4.970	0.1169	66	0.3714	87	5.987	370	0.1044	27	107	1910	101	11-Feb-03
0377K.1-1	72	22903	320	5.691	0.1393	43	1.1973	419	22.996	1128	0.1191	23	229	2219	54	21-Jan-04
C101E.1-3	207	475	2.30	5.842	0.1318	29	0.3782	85	6.872	224	0.1083	30	97	2122	38	11-Feb-03
C101D.1-14	130	1007	7.76	5.996	0.1296	79	0.4049	94	7.237	480	0.1170	31	105	2093	108	11-Feb-03
C101D.11-1	161	71	0.44	7.181	0.1381	75	0.3964	95	7.548	454	0.1143	208	98	2204	94	11-Feb-03
C101D.9-1	142	479	3.37	8.248	0.1349	41	0.4140	93	7.699	300	0.1186	35	103	2162	53	11-Feb-03
C101D.1-5	101	233	2.30	13.167	0.1313	120	0.4321	113	7.826	745	0.1016	59	109	2116	160	11-Feb-03

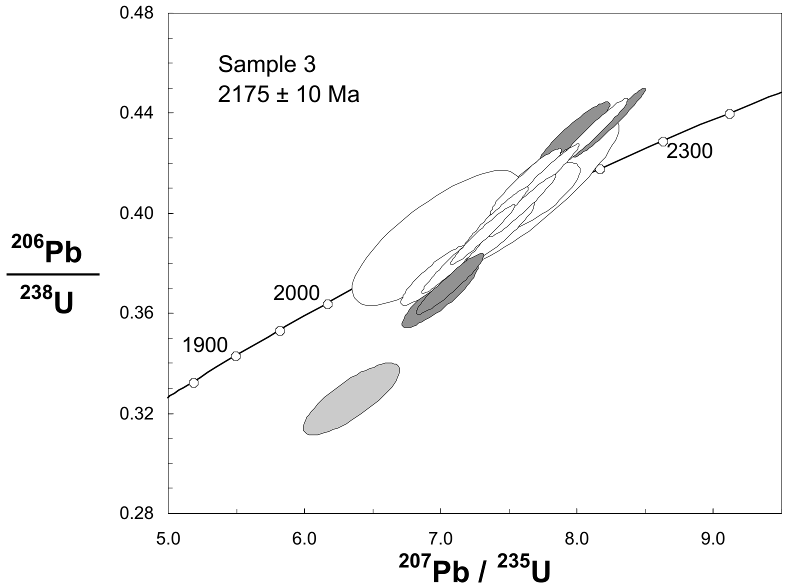

Fig. S3. SHRIMP U–Pb data for monazite from Sample 3, BD-2.

Sample 4

Sample details

Sample 4 comprises pyritic black shale of the Mt McRae Shale collected from the Mt Newman iron-ore deposit (Fig. 1). All specimens contain minute irregular monazite that typically engulfs metamorphic sericite and quartz.

Analytical notes

These data were collected from several mounts over four analytical sessions. The early sessions were not very productive; most of the better-quality data come from the last session, analysing a more rigorously selected collection of grains (mount 04-106)

Interpretation

The sample grains all have low U, leading to generally poor-quality U–Pb data. There is an overall trend to high U–Pb concordance values, suggesting that the matrix corrections have not been accurate for this sample, possibly because of some unidentified and unusual (and not investigated) trace element substitution. Because high values of Pb/U cannot be attributed to any of the normal Pb-loss mechanisms, we consider that the samples are almost certainly concordant, and consequently have retained data with apparent concordance ("conc.") up to 112%.

The low U content makes these data susceptible to corruption by quite small quantities of common Pb, and the majority of data have been excluded from age considerations on these grounds. However, in order to have a sufficient data set, we retained data with 4f206 up to 2%.Amongst the better data there are two analyses from one grain, which are distinct old outliers. One other analysis from this grain is also old, but imprecise, while a fourth is consistent with the main data group. All four analyses have been disregarded – the grain may include a component grown during the 2400 Ma event. The $^{208}Pb/^{232}Th$ data have been assessed to help choose only the best U–Pb data. There are three analyses with distinctly low $^{208}Pb/^{232}Th$. The mean $^{208}Pb/^{232}Th$ date is consistent with the $^{207}Pb/^{206}Pb$ date, regardless of whether these three analyses are included. Omitting them increases the mean $^{208}Pb/^{232}Th$ date, but it decreases the $^{207}Pb/^{206}Pb$ date. The weighted mean $^{207}Pb/^{206}Pb$ age for the 16 best analyses is 2168 ± 34 Ma (MSWD = 1.6), changing to 2179 ± 32 Ma (MSWD = 1.8) if the three low-$^{208}Pb/^{232}Th$ points are retained.

Date

We consider the best value for the age of growth of this low-U monazite is 2175 ± 35 Ma.

TABLE DR4. SHRIMP DATA FOR MONAZITE IN SAMPLE 4, MT NEWMAN IRON-ORE DEPOSIT

Analysis	U (ppm)	Th (ppm)	Th/U	f206 (%)	$^{207}Pb^*/^{206}Pb^*$	±	$^{206}Pb^*/^{238}U$	±	$^{207}Pb^*/^{235}U$	±	$^{208}Pb^*/^{232}Th$	±	conc. (%)	$^{207}Pb^*/^{206}Pb^*$ Age (Ma)	±	Date
Self-consistent subset, in order of $^{207}Pb/^{206}Pb$																
04106O.1-1b	*22*	*9963*	*448*	1.661	0.1244	73	*0.3977*	*190*	*6.819*	*536*	*0.1137*	*12*	*107*	2020	104	15-Oct-04
04106E.1-7b	*40*	*13618*	*338*	1.791	0.1264	67	*0.3904*	*159*	*6.802*	*469*	*0.1120*	*11*	*104*	2048	93	15-Oct-04
04106A.1-1b	*40*	*13517*	*340*	0.990	0.1299	40	*0.4049*	*132*	*7.252*	*341*	*0.1126*	*10*	*105*	2097	55	15-Oct-04
04106E.1-3a	39	17392	444	0.598	0.1300	37	0.4204	158	7.536	373	0.1115	11	108	2098	50	15-Oct-04
04106E.1-6a	48	15000	315	1.280	0.1316	48	0.4104	149	7.448	400	0.1156	11	105	2120	64	15-Oct-04
04106K.1-1a	49	17179	347	0.727	0.1322	41	0.4462	179	8.131	430	0.1109	11	112	2127	54	15-Oct-04
C68E.1-4a	23	12074	523	0.921	0.1325	36	0.4184	125	7.645	324	0.1141	15	106	2132	47	13-Jan-03
04106A.1-1a	45	17195	380	0.627	0.1326	35	0.4442	148	8.121	361	0.1141	11	111	2133	46	15-Oct-04
C101G.1-6a	35	10117	291	1.570	0.1330	31	0.4144	117	7.600	290	0.1131	25	105	2138	41	11-Feb-03
04106I.1-1b	*51*	*18861*	*370*	0.000	0.1348	31	*0.4080*	*155*	*7.582*	*352*	*0.1126*	*11*	*102*	2161	40	15-Oct-04
C68E.1-2a	34	13627	399	1.626	0.1364	45	0.4175	146	7.854	394	0.1183	27	103	2183	57	5-Mar-04
04106M.1-1a	34	20718	613	1.785	0.1365	78	0.4295	206	8.081	628	0.1153	11	106	2183	100	15-Oct-04
C68E.1-1a	16	10223	640	0.000	0.1372	31	0.4155	186	7.858	413	0.1133	16	102	2192	40	13-Jan-03
04106K.1-1b	*39*	*14307*	*365*	0.000	0.1394	30	*0.4062*	*159*	*7.808*	*366*	*0.1142*	*11*	*99*	2220	38	15-Oct-04
C68E.1-4b	*33*	*19742*	*590*	1.459	0.1405	49	*0.4227*	*162*	*8.188*	*447*	*0.1172*	*16*	*102*	2233	60	13-Jan-03
04106E.1-7a	47	16922	362	0.060	0.1450	32	0.4268	175	8.530	414	0.1122	11	100	2287	37	15-Oct-04
Apparent Pb/Th–Pb/U discordance (low $^{208}Pb/^{232}Th$)																
04106H.1-1a	30	15622	520	0.000	0.1381	35	0.4140	197	7.881	444	0.1081	10	101	2203	44	15-Oct-04
04106I.1-1a	61	24702	404	0.000	0.1429	29	0.4084	162	8.047	374	0.1086	11	98	2263	35	15-Oct-04
04106J.1-1a	30	18969	632	1.848	0.1267	85	0.3701	203	6.466	583	0.1078	11	99	2053	119	15-Oct-04
Anomalous grain (?)																
04106F.1-1a	32	40193	1259	0.000	0.1500	34	0.4462	198	9.225	480	0.1205	11	101	2345	38	15-Oct-04
04106F.1-1b	*30*	*36163*	*1210*	1.824	0.1331	72	*0.4191*	*202*	*7.690*	*585*	*0.1182*	*11*	*105*	2139	95	15-Oct-04
04106F.1-2a	55	6591	120	0.000	0.1509	28	0.4516	168	9.397	407	0.1210	17	102	2357	32	15-Oct-04
04106F.1-2b	*52*	*6430*	*123*	2.647	0.1488	76	*0.4323*	*171*	*8.870*	*591*	*0.1190*	*17*	*99*	2332	88	15-Oct-04
4f206>2% and/or discordant																
04106O.1-1a	26	13536	515	1.011	0.1209	60	0.4248	210	7.085	518	0.1129	11	116	1970	89	15-Oct-04
04106E.1-3b	*26*	*10195*	*392*	2.028	0.1347	71	*0.3959*	*156*	*7.353*	*500*	*0.1153*	*11*	*100*	2160	92	15-Oct-04
C101G.1-1a	14	8285	593	2.240	0.1368	56	0.3617	132	6.821	387	0.0955	22	91	2187	71	11-Feb-03
04106E.1-6b	*39*	*13185*	*336*	2.778	0.1245	92	*0.3888*	*151*	*6.672*	*568*	*0.1140*	*11*	*105*	2021	131	15-Oct-04
04106H.1-1b	*22*	*11106*	*508*	3.354	0.1463	110	0.3881	191	7.828	723	0.1053	11	92	2303	129	15-Oct-04
04106M.1-2a	30	17006	573	4.026	0.1327	119	0.4200	206	7.685	801	0.1146	11	106	2134	156	15-Oct-04
C101A.1-1b	*12*	*7353*	*598*	4.444	0.1312	76	*0.4042*	*144*	*7.308*	*511*	*0.1172*	*26*	*104*	2113	101	11-Feb-03

C101g.1-5a	16	5013	308	5.014	0.1208	84	0.4112	149	6.851	550	0.1137	26	113	1968	124	11-Feb-03
C68A.1-3a	45	20090	444	5.014	0.1366	85	0.3864	159	7.279	565	0.1117	26	96	2185	108	5-Mar-04
C68A1.1-1b	*75*	*36910*	*494*	5.301	0.1377	65	*0.4135*	*149*	*7.852*	*490*	*0.1189*	*14*	*101*	2199	82	13-Jan-03
C68E2.1-2a	16	12145	750	5.506	0.1847	140	0.3953	192	10.069	946	0.1099	19	80	2696	125	13-Jan-03
04106K.1-2a	20	10588	526	5.640	0.1151	161	0.4311	248	6.841	1041	0.1148	12	123	1881	252	15-Oct-04
04106M.1-1b	*17*	*10683*	*640*	5.955	0.0957	165	*0.3924*	*230*	*5.175*	*942*	*0.1164*	*11*	*138*	1541	324	15-Oct-04
C101H.1-1a	26	14639	557	6.064	0.1286	58	0.4035	112	7.156	389	0.1202	26	105	2079	79	11-Feb-03
C68E.1-5a	18	10994	597	6.189	0.1718	97	0.4131	180	9.787	731	0.1105	16	87	2576	94	13-Jan-03
C101A.1-1a	16	9484	581	6.937	0.1402	95	0.4159	144	8.041	628	0.1186	26	101	2230	118	11-Feb-03
C68F.1-2a	28	13738	495	8.991	0.1332	120	0.3932	170	7.218	742	0.1043	26	100	2140	158	5-Mar-04
C68C1.1-1a	33	9463	290	9.180	0.1499	121	0.3065	154	6.333	630	0.1111	21	74	2344	138	13-Jan-03
C101G.1-1b	*18*	*9643*	*539*	9.257	0.1213	154	*0.2914*	*115*	*4.872*	*654*	*0.0799*	*18*	*83*	1975	227	11-Feb-03
C68E.2-6a	16	10256	634	9.683	0.1392	202	0.4271	206	8.195	1267	0.1163	27	103	2217	252	5-Mar-04
C101C.1-1a	29	12814	446	10.361	0.1657	106	0.3840	128	8.773	649	0.1111	25	83	2515	107	11-Feb-03
C101C.1-2a	19	9646	507	11.222	0.1546	144	0.3220	133	6.864	713	0.0955	22	75	2398	158	11-Feb-03
C68A.1-1a	51	22266	436	11.419	0.1287	94	0.3926	112	6.966	564	0.1094	13	103	2080	129	13-Jan-03
C101G.1-8a	28	9744	343	14.868	0.1108	147	0.3501	116	5.348	732	0.1014	22	107	1812	241	11-Feb-03
C101G.1-2a	15	5954	392	15.749	0.1646	214	0.2389	135	5.421	782	0.0981	23	55	2503	219	11-Feb-03
C101G.1-4a	78	7347	95	17.593	0.1002	129	0.2334	88	3.224	434	0.1074	25	83	1627	239	11-Feb-03
C101C.1-3a	19	8387	430	17.603	0.1844	214	0.4109	189	10.448	1324	0.1162	27	82	2693	192	11-Feb-03
C68E.1-3a	29	13236	462	17.856	0.1455	136	0.4005	126	8.038	811	0.1086	15	95	2294	160	13-Jan-03
C68E.2-7a	20	11180	554	19.554	0.1440	232	0.3949	196	7.839	1335	0.1088	25	94	2276	278	5-Mar-04
C101G.1-7a	22	8256	369	23.341	0.0875	193	0.2913	103	3.514	778	0.1034	23	120	1371	425	11-Feb-03
C68A.1-4a	23	16814	735	23.501	0.1588	254	0.3750	237	8.214	1441	0.1172	27	84	2443	271	5-Mar-04
C68F.1-1a	23	10629	467	23.935	0.2006	233	0.2297	141	6.353	869	0.1073	14	47	2831	190	13-Jan-03
C101C.1-1b	*16*	*7067*	*436*	26.373	0.2394	239	*0.3929*	*161*	*12.972*	*1419*	*0.1149*	*26*	*69*	3116	159	11-Feb-03
C68E.2-5a	23	12288	531	27.553	0.1733	243	0.3975	195	9.497	1429	0.1011	24	83	2589	234	5-Mar-04
C68D.1-1a	22	13807	624	28.662	0.1170	316	0.3147	198	5.076	1409	0.0865	21	92	1911	485	5-Mar-04
C101G.1-2b	*15*	*3770*	*254*	28.717	0.1882	361	*0.1434*	*71*	*3.721*	*736*	*0.0897*	*20*	*32*	2727	316	11-Feb-03
C101G.1-3a	23	5661	249	30.113	0.1122	235	0.2785	111	4.308	912	0.0983	23	86	1835	380	11-Feb-03
C101G.1-9a	46	10353	227	36.811	0.0961	223	0.2582	115	3.420	804	0.0919	21	96	1549	436	11-Feb-03

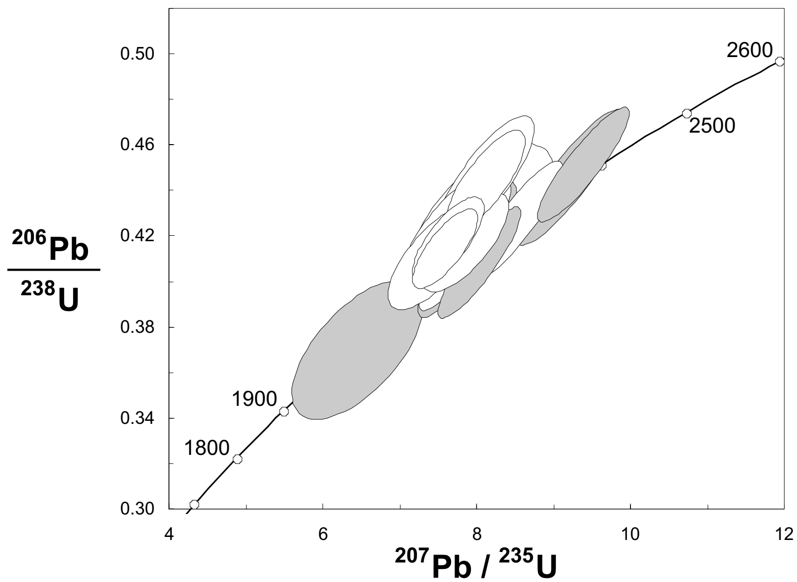

Fig. DR4. SHRIMP U–Pb data for monazite from Sample 4, Mt Newman iron-ore deposit. Grey-shaded data are from one apparently older grain and three analyses with low $^{208}Pb/^{232}Th$. Data with 4f206 >2% or high discordance are not plotted.

Sample 5

Sample details

Sample 5 comprises black shale of the Jeerinah Formation intersected in drill-hole FVG-1 (Fig. 1) from a depth of 776.72 m. Monazite is present throughout the Jeeinah Formation in this drill-hole, but only in a single sample were crystals sufficiently coarse for SHRIMP analysis.

Analytical notes

The data were obtained in one full-day analytical session, with a few additional points from a separate session.

Interpretation

One analysed grain has >4% Th and >2500 ppm U, more typical of magmatic rather than hydrothermal monazite. It is distinctly older than the main body of data and is interpreted to be detrital. Approximately a quarter of the data were disregarded on the grounds of discordance or high common Pb. The remaining 25 analyses form a single group, though some low-U samples have distinctly poorer $^{207}Pb/^{206}Pb$ precision than others, and carry little weight in the result. The main group has a weighted mean $^{207}Pb/^{206}Pb$ age of 2154.6 ± 9.1 Ma (MSWD = 1.3). If selection is restricted to 4f206 < 1% and discordance <~5%, this changes slightly to 2152.5 ± 8.3 Ma (*n* = 18; MSWD = 1.13).

Date

The age of hydrothermal monazite formation is 2153 ± 10 Ma. The ± 10 Ma uncertainty is applied because almost all data contributing to the averaged age are from a single analytical session (see above).

TABLE DR5. SHRIMP DATA FOR MONAZITE IN SAMPLE 5, FVG-1

Analysis	U (ppm)	Th (ppm)	Th/U	f206 (%)	$^{207}Pb^*/^{206}Pb^*$	±	$^{206}Pb^*/^{238}U$	±	$^{207}Pb^*/^{235}U$	±	$^{208}Pb^*/^{232}Th$	±	conc. (%)	$^{207}Pb^*/^{206}Pb^*$ Age (Ma)	±	Date
Main data set, in order of $^{207}Pb/^{206}Pb$																
03101D.1-2a	54	711	13.1	1.048	0.1288	28	0.4180	133	7.422	296	0.1158	21	108	2081	38	13-Dec-03
03101D.1-1b	*78*	*93*	*1.2*	0.512	0.1299	22	*0.3751*	*124*	*6.717*	*259*	*0.1051*	*45*	*98*	2096	30	13-Dec-03
03101G.1-1b	*40*	*630*	*15.7*	0.535	0.1306	30	*0.3460*	*117*	*6.229*	*266*	*0.0919*	*20*	*91*	2106	41	13-Dec-03
03101G.1-2a	22	402	17.9	0.216	0.1308	52	0.3520	152	6.349	386	0.0939	22	92	2109	70	13-Dec-03
03101G.1-1a	41	991	24.3	0.188	0.1320	19	0.3711	122	6.755	250	0.1012	24	96	2125	25	13-Dec-03
03101D.1-1a	65	72	1.1	0.000	0.1325	11	0.4164	127	7.609	247	0.1143	42	105	2132	15	13-Dec-03
03101F.1-1b	*96*	*100*	*1.0*	0.274	0.1326	16	*0.3571*	*112*	*6.529*	*227*	*0.1079*	*43*	*92*	2133	21	13-Dec-03
03101B.1-1a	76	104	1.4	0.267	0.1327	16	0.4064	121	7.437	246	0.1072	49	103	2134	20	13-Dec-03
03101F.1-1a	75	107	1.4	0.061	0.1328	12	0.4011	119	7.341	234	0.1148	36	102	2135	16	13-Dec-03
0308B.1-1a	83	545	6.6	0.201	0.1332	15	0.4157	89	7.632	191	0.1166	35	105	2140	19	16-Oct-03
03101B.1-1b	*80*	*50*	*0.6*	0.345	0.1335	20	*0.4103*	*122*	*7.551*	*260*	*0.1187*	*55*	*103*	2144	26	13-Dec-03
03101H.1-1b	*60*	*359*	*6.0*	0.132	0.1335	15	*0.3621*	*110*	*6.664*	*223*	*0.1024*	*26*	*93*	2144	20	13-Dec-03
03101A.1-1b	*37*	*759*	*20.4*	0.053	0.1342	19	*0.3987*	*137*	*7.380*	*283*	*0.1145*	*21*	*100*	2154	25	13-Dec-03
03101B.1-2a	107	144	1.3	1.417	0.1342	50	0.3790	120	7.013	351	0.1018	38	96	2154	65	13-Dec-03
03101D.1-2b	*62*	*881*	*14.1*	0.201	0.1343	22	*0.3997*	*131*	*7.401*	*282*	*0.1124*	*23*	*101*	2155	29	13-Dec-03
03101H.1-2b	*156*	*166*	*1.1*	0.034	0.1345	8	*0.3782*	*105*	*7.013*	*205*	*0.1055*	*28*	*96*	2157	11	13-Dec-03
03101H.1-3a	40	82	2.0	0.000	0.1344	15	0.3591	116	6.658	233	0.1000	34	92	2157	19	13-Dec-03
03101H.1-2a	150	280	1.9	0.000	0.1346	9	0.4034	113	7.485	220	0.1162	26	101	2158	11	13-Dec-03
03101G.1-3a	28	297	10.8	0.000	0.1347	23	0.3533	146	6.562	303	0.0957	23	90	2160	29	13-Dec-03
03101H.1-1a	68	339	5.0	0.190	0.1351	15	0.3918	119	7.299	242	0.1073	23	98	2166	19	13-Dec-03
0308C.1-1a	42	475	11.3	0.108	0.1360	18	0.3801	90	7.127	201	0.1113	32	95	2177	23	16-Oct-03
03101D.1-3b	*136*	*552*	*4.1*	0.051	0.1360	10	*0.4191*	*119*	*7.859*	*236*	*0.1128*	*27*	*104*	2177	12	13-Dec-03
03101A.1-1a	46	1015	22.2	0.112	0.1364	15	0.3906	122	7.346	251	0.1079	19	97	2182	20	13-Dec-03
03101D.1-3a	100	560	5.6	0.067	0.1369	10	0.4306	123	8.125	245	0.1151	22	106	2188	13	13-Dec-03
03101C.1-1b	*12*	*74*	*6.1*	0.156	0.1400	74	*0.3849*	*190*	*7.428*	*554*	*0.1060*	*37*	*94*	2227	92	13-Dec-03
Not used (discordant)																
03101G.1-3b	*26*	*207*	*8.0*	0.138	0.1305	42	*0.3138*	*130*	*5.647*	*306*	*0.0868*	*26*	*84*	2105	56	13-Dec-03
03101H.1-3b	*56*	*102*	*1.8*	0.002	0.1340	16	*0.3241*	*105*	*5.986*	*212*	*0.0905*	*33*	*84*	2150	20	13-Dec-03
03101G.1-2b	*20*	*182*	*9.0*	0.592	0.1240	59	*0.3011*	*140*	*5.148*	*353*	*0.0892*	*28*	*84*	2015	84	13-Dec-03
03-08C.1-1b	*26*	*490*	*18.6*	0.000	0.1427	45	*0.3507*	*122*	*6.899*	*332*	*0.1005*	*41*	*86*	2260	55	17-Jan-04
03-08C.1-1a	28	177	6.3	0.442	0.1317	40	0.4473	152	8.125	378	0.1104	55	112	2121	53	17-Jan-04
03101C.1-1a	15	62	4.2	0.130	0.1280	33	0.4471	183	7.893	396	0.1156	40	115	2071	45	13-Dec-03
Not used (high common Pb)																
03101B.1-3a	58	280	4.8	4.030	0.1481	64	0.3842	142	7.844	461	0.1053	29	90	2324	75	13-Dec-03

03101B.1-3b	*45*	*254*	*5.6*	4.582	0.1291	130	*0.3654*	*132*	*6.505*	*693*	*0.0966*	*32*	*96*	2086	179	13-Dec-03
03101B.1-2b	*152*	*428*	*2.8*	5.605	0.1301	79	*0.3485*	*123*	*6.253*	*446*	*0.0922*	*29*	*92*	2100	107	13-Dec-03
Probably inherited																
03-08D.1-1b	*2607*	*42766*	*16.4*	0.404	0.2008	18	*0.5715*	*116*	*15.824*	*366*	*0.1317*	*34*	*103*	2833	15	17-Jan-04
03-08D.1-1a	4397	50743	11.5	0.077	0.2003	12	0.5845	111	16.145	332	0.1467	37	105	2829	10	17-Jan-04

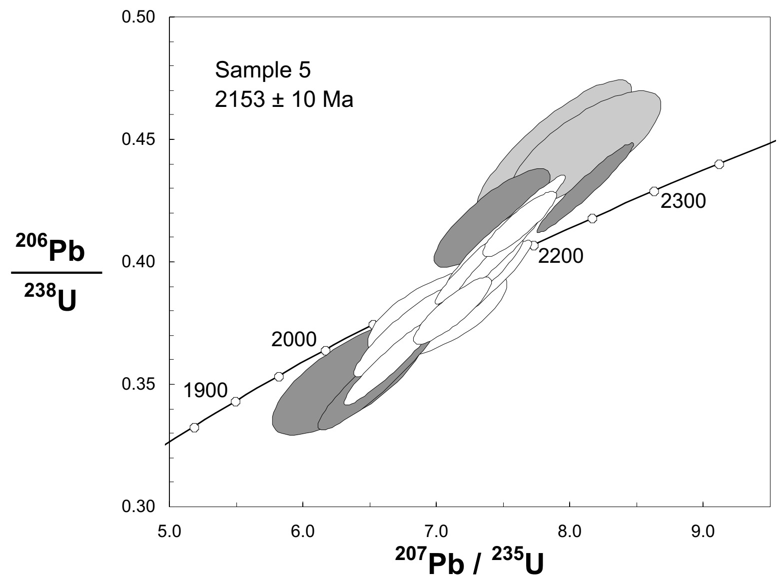

Fig. DR5. SHRIMP U–Pb data for monazite from Sample 5, FVG-1.

Sample 6

Sample details

Sample 6 comprises pyritic black shale of the Mt McRae Shale collected from the Mt Tom Price iron-ore deposit (Fig. 1). Monazite crystals are present in most specimens where they occur as minute (typically <20 μm), inclusion-rich crystals.

Analytical notes

This is a large data set, from several analytical sessions.

Interpretation

Data for this sample separate strongly into two groups on the basis of U and Th contents. One has high U (>~200 ppm), low Th (<3000 ppm) and consequently low Th/U (mostly <10). The other group has low U (<100 ppm with only a few >50 ppm), significantly higher Th (>7500 ppm) and Th/U >~200. There are also two distinct concentrations of $^{207}Pb/^{206}Pb$ dates, at ~2200 Ma and ~2400 Ma (Fig. S6). The dates partially correlate with the two chemical classes, but there is appreciable crossover (Figs. S6 and S7). There are only two good-quality analyses that appear to be of mixed U-Th composition, but several analyses that clearly fall in one or other of the chemical groups have intermediate ages, suggesting mixing.

Thirty-nine analyses, predominantly of low-U samples, have >2% common Pb and 14 are too discordant to be reliable (though their $^{207}Pb/^{206}Pb$ dates are consistent with better data). Of the better-quality high-U analyses, 20 define a single age population with a weighted mean $^{207}Pb/^{206}Pb$ age of 2399.2 ± 5.5 Ma (MSWD = 0.85). The other six high-U analyses give younger dates, some of which agree with the dominant age in the low-U data, while others appear to be mixtures. The main $^{207}Pb/^{206}Pb$ age defined by the low-U data is 2216 ± 13 Ma (MSWD = 1.08; n = 22). Some of the low-U data give the same $^{207}Pb/^{206}Pb$ date as the dominant high-U group.

Dates

There were two main episodes of monazite growth, at 2399 ± 6 Ma and 2216 ± 13 Ma. Two sources of material for monazite growth appear to have been tapped in both fluid events, though each dominates the contribution to the monazite in one of the events.

TABLE DR6. SHRIMP DATA FOR MONAZITE IN SAMPLE 6, MT TOM PRICE IRON-ORE DEPOSIT

Analysis	U (ppm)	Th (ppm)	Th/U	f206 (%)	$^{207}Pb^*/^{206}Pb^*$	±	$^{206}Pb^*/^{238}U$	±	$^{207}Pb^*/^{235}U$	±	$^{208}Pb^*/^{232}Th$	±	conc. (%)	$^{207}Pb^*/^{206}Pb^*$ Age (Ma)	±	Date
Main high-U data set, in order of $^{207}Pb/^{206}Pb$																
0323I.1-4b	*284*	*1046*	*3.68*	0.822	0.1572	21	*0.4620*	*84*	*10.015*	*230*	*0.1325*	*39*	101	2426	22	17-Jan-04
03-08H.1-2b	*785*	*1869*	*2.38*	1.095	0.1567	19	*0.4664*	*99*	*10.076*	*255*	*0.1170*	*41*	102	2420	21	17-Jan-04
0324G.2-1b	*359*	*964*	*2.68*	0.585	0.1566	19	*0.3929*	*70*	*8.485*	*191*	*0.1180*	*36*	88	2420	20	25-Oct-03
0323I.1-4a	316	1241	3.93	0.889	0.1565	14	0.4567	81	9.853	200	0.1183	42	100	2418	15	17-Jan-04
0324E.1-1a	319	1608	5.04	0.593	0.1562	12	0.4653	79	10.022	191	0.1235	33	102	2415	13	17-Jan-04
0323I.1-3a	432	1988	4.60	0.570	0.1558	8	0.4421	74	9.494	170	0.1286	35	98	2410	9	16-Oct-03
0324G.2-1a	409	1100	2.69	0.288	0.1554	17	0.4281	62	9.172	176	0.1195	38	95	2406	19	25-Oct-03
03-08H.1-5a	480	1159	2.41	1.303	0.1553	22	0.4737	84	10.140	235	0.1142	52	104	2405	24	17-Jan-04
0323B.1-2b	*381*	*2109*	*5.53*	0.752	0.1551	17	*0.4812*	*86*	*10.287*	*222*	*0.1359*	*35*	*105*	2402	18	17-Jan-04
0308A.1-1a	453	1231	2.72	0.920	0.1549	10	0.4415	74	9.431	174	0.1231	35	98	2401	11	16-Oct-03
0323B.1-2a	251	1706	6.80	0.716	0.1549	15	0.4813	86	10.282	214	0.1285	32	105	2401	16	17-Jan-04
0308H.1-1a	597	714	1.20	0.866	0.1549	10	0.4298	74	9.178	174	0.1054	31	96	2400	11	16-Oct-03
0324E.1-1b	*317*	*2706*	*8.53*	1.517	0.1548	20	*0.4292*	*79*	*9.160*	*210*	*0.1240*	*34*	*96*	2399	21	17-Jan-04
0308H.1-2a	565	2541	4.50	0.582	0.1547	7	0.4323	73	9.219	164	0.1109	29	97	2398	8	16-Oct-03
0323B.1-1a	479	1434	3.00	0.425	0.1546	9	0.5046	82	10.758	191	0.1322	38	110	2398	10	17-Jan-04
0323B.1-3a	371	2777	7.49	0.591	0.1542	12	0.4717	82	10.030	198	0.1193	30	104	2393	14	17-Jan-04
0324E.1-1a	211	1547	7.33	0.353	0.1540	16	0.4360	69	9.258	184	0.1237	32	98	2391	18	25-Oct-03
0323B.1-2a	345	2744	7.96	0.849	0.1537	10	0.4375	74	9.269	173	0.1228	33	98	2387	11	16-Oct-03
0323I.1-2a	640	1654	2.58	0.491	0.1534	7	0.4035	66	8.533	148	0.1123	32	92	2384	8	16-Oct-03
03-08H.1-2a	616	2272	3.69	1.458	0.1527	15	0.4539	87	9.554	211	0.0837	33	102	2376	17	17-Jan-04
High U, younger																
0324G.1-4a	210	367	1.75	0.627	0.1479	15	0.4559	86	9.298	205	0.1199	39	104	2322	17	17-Jan-04
0324G.1-1a	214	1008	4.71	1.003	0.1462	22	0.4142	82	8.350	213	0.1212	35	97	2302	26	17-Jan-04
0324G.1-2a	364	667	1.83	0.927	0.1436	18	0.4670	106	9.242	248	0.1198	35	109	2270	22	17-Jan-04
0323B.2-1a	469	5408	11.54	1.381	0.1412	12	0.3978	67	7.747	152	0.1084	28	96	2242	15	16-Oct-03
0324G.1-2a	357	769	2.15	0.240	0.1408	16	0.3943	64	7.653	160	0.1188	56	96	2237	20	25-Oct-03
03-08H.1-1a	332	5146	15.48	1.000	0.1391	25	0.3836	91	7.355	224	0.1012	29	94	2215	31	17-Jan-04
Main low-U data set, in order of $^{207}Pb/^{206}Pb$																
0323E.1-1a	21	10277	499.97	1.030	0.1458	36	0.4063	129	8.170	341	0.1124	29	96	2298	43	16-Oct-03
03-08G.1-1b	*61*	*11445*	*186.10*	0.284	0.1434	30	*0.4033*	*134*	*7.976*	*325*	*0.0970*	*24*	*96*	2269	37	17-Jan-04
03-08L.1-2b	*18*	*8567*	*479.71*	1.323	0.1434	77	*0.4310*	*195*	*8.520*	*609*	*0.1246*	*30*	*102*	2268	93	17-Jan-04
0324J.2-1a	25	11640	474.71	0.465	0.1427	29	0.4083	237	8.033	509	0.1162	28	98	2260	35	17-Jan-04
0324D.1-2a	49	16614	335.85	0.162	0.1413	19	0.4369	116	8.514	261	0.1161	28	104	2243	23	17-Jan-04
0324F.1-2b	*58*	*12929*	*223.53*	0.121	0.1410	16	*0.4106*	*103*	*7.980*	*229*	*0.1230*	*29*	*99*	2239	20	17-Jan-04

0324B.1-1a	20	8625	421.87	0.307	0.1403	42	0.4376	180	8.464	454	0.1192	27	105	2231	52	25-Oct-03
0308L.1-1a	29	9801	332.29	0.000	0.1399	18	0.4479	120	8.640	266	0.1174	30	107	2226	22	16-Oct-03
0324B.2-1b	*30*	*9880*	*325.68*	0.000	0.1397	23	*0.4167*	*145*	*8.026*	*318*	*0.1232*	*30*	*101*	2224	29	17-Jan-04
0324B.2-1a	23	9200	398.25	1.906	0.1397	62	0.4170	180	8.032	508	0.1201	30	101	2223	77	17-Jan-04
0324B.1-2a	26	7913	302.41	1.126	0.1396	51	0.4052	150	7.798	425	0.1181	27	99	2222	63	25-Oct-03
0323F.1-1b	*28*	*9618*	*340.20*	0.020	0.1393	20	*0.3924*	*110*	*7.537*	*245*	*0.1187*	*30*	*96*	2219	24	16-Oct-03
0308L.1-1b	*24*	*7719*	*322.77*	0.136	0.1386	20	*0.3971*	*108*	*7.590*	*243*	*0.1158*	*29*	*98*	2210	25	16-Oct-03
0324B.2-1	27	10410	389.35	0.812	0.1386	42	0.3978	146	7.601	379	0.1172	26	98	2210	52	25-Oct-03
0324B.1-2b	*30*	*8432*	*277.33*	0.000	0.1385	21	*0.4359*	*147*	*8.321*	*318*	*0.1336*	*32*	*106*	2208	27	17-Jan-04
0324B.1-2a	35	9398	267.43	0.000	0.1381	20	0.4398	131	8.377	285	0.1262	31	107	2204	25	17-Jan-04
0323F.1-3a	70	16652	236.58	0.000	0.1379	17	0.4381	104	8.328	228	0.1213	29	106	2200	21	17-Jan-04
0323F.1-1a	34	11545	343.23	0.216	0.1375	19	0.4258	116	8.075	255	0.1179	30	104	2196	24	16-Oct-03
0323E.1-3a	35	9141	259.02	0.164	0.1367	22	0.4546	135	8.567	298	0.1240	30	110	2186	28	17-Jan-04
0324F.1-1a	45	8164	180.95	0.329	0.1351	32	0.3811	116	7.097	288	0.1154	27	96	2165	42	25-Oct-03
0324H.1-1a	25	9745	395.84	0.226	0.1346	26	0.4427	157	8.218	343	0.1186	28	109	2159	34	17-Jan-04
0323E.1-1b	*18*	*9038*	*504.34*	1.159	0.1293	43	*0.3817*	*125*	*6.803*	*326*	*0.1107*	*28*	*100*	2088	58	16-Oct-03
low U, older																
0324B.1-1a	41	13366	328.09	0.624	0.1553	31	0.4385	125	9.392	336	0.1131	27	97	2405	34	17-Jan-04
0308H.1-4a	22	8533	383.91	1.630	0.1552	22	0.4657	87	9.969	240	0.1175	35	102	2405	24	17-Jan-04
0324J.1-3a	22	9678	433.86	0.689	0.1547	47	0.4316	179	9.207	498	0.1151	26	96	2399	52	25-Oct-03
0308L.1-3a	28	9365	338.55	0.694	0.1512	37	0.4453	160	9.286	416	0.1168	28	101	2360	42	17-Jan-04
0324F.1-1b	*39*	*14972*	*385.09*	1.374	0.1507	48	*0.3842*	*125*	*7.982*	*372*	*0.0973*	*23*	*89*	2354	54	17-Jan-04
0324H.1-1a	45	11805	260.69	0.401	0.1499	50	0.4477	212	9.250	564	0.1210	32	102	2344	57	25-Oct-03
0308L.1-3b	*21*	*8350*	*393.05*	0.281	0.1497	34	*0.4595*	*177*	*9.488*	*437*	*0.1229*	*29*	*104*	2343	39	17-Jan-04
0308E.1-1a	35	13124	373.03	0.000	0.1494	16	0.4470	112	9.206	259	0.1157	30	102	2339	18	16-Oct-03
0323E.1-2a	24	11934	496.52	1.026	0.1483	40	0.4545	164	9.294	433	0.1200	29	104	2327	46	17-Jan-04
0324J.3-1a	28	10710	382.85	0.000	0.1477	22	0.4248	136	8.649	316	0.1203	29	98	2319	26	17-Jan-04
0323A.1-2a	28	12982	456.36	1.315	0.1473	38	0.4269	130	8.667	359	0.1156	30	99	2314	44	16-Oct-03
uncertain U, Th classification																
0323I.1-4a	191	3300	17.30	1.334	0.1551	15	0.3977	74	8.505	186	0.1237	34	90	2403	17	16-Oct-03
0308G.1-1a	98	6807	69.44	0.497	0.1468	40	0.4521	136	9.152	382	0.1113	28	104	2309	47	17-Jan-04
Old outlier																
0324D.1-2b	*36*	*11601*	*326.71*	0.755	0.1809	37	*0.4497*	*137*	*11.213*	*426*	*0.1233*	*29*	*90*	2661	34	17-Jan-04
Not used (discordant)																
0324J.1-2a	62	11380	184.73	1.932	0.1333	63	0.3452	95	6.343	347	0.1248	30	89	2141	83	17-Jan-04
0323F.1-3b	*70*	*15495*	*222.52*	0.000	0.1335	20	*0.4315*	*109*	*7.945*	*242*	*0.1249*	*30*	*108*	2145	26	17-Jan-04
0323B.1-3b	*311*	*1294*	*4.16*	0.905	0.1564	13	*0.4987*	*85*	*10.756*	*211*	*0.1382*	*41*	*108*	2417	14	17-Jan-04
0324B.2-2b	*36*	*10984*	*304.29*	0.550	0.1331	27	*0.4317*	*143*	*7.922*	*316*	*0.1247*	*30*	*108*	2139	35	17-Jan-04

0323E.1-2b	*19*	*7242*	*373.28*	0.500	0.1388	34	*0.4552*	*164*	*8.713*	*393*	*0.1374*	*34*	*109*	2213 43	17-Jan-04
0323F.1-1b	*3609*	*12907*	*3.58*	0.349	0.1316	25	*0.4339*	*145*	*7.872*	*313*	*0.1245*	*30*	*110*	2119 33	17-Jan-04
0323B.1-1b	*421*	*801*	*1.90*	0.600	0.1541	16	*0.5021*	*91*	*10.670*	*228*	*0.1454*	*44*	*110*	2392 17	17-Jan-04
0324B.2-2a	34	10402	302.93	0.331	0.1363	24	0.4618	131	8.678	300	0.1243	30	112	2181 31	17-Jan-04
0308L.1-4b	*23*	*8558*	*369.31*	0.128	0.1360	29	*0.4612*	*174*	*8.651*	*387*	*0.1280*	*30*	*112*	2177 38	17-Jan-04
0308L.1-2a	22	9145	420.90	1.430	0.1398	53	0.4742	168	9.138	482	0.1163	28	112	2224 65	17-Jan-04
0324F.1-2a	58	13832	236.78	0.411	0.1316	20	0.4497	125	8.158	266	0.1232	30	113	2119 27	17-Jan-04
0323F.1-1a	30	10347	348.88	0.251	0.1337	26	0.4569	136	8.424	311	0.1208	30	113	2147 35	17-Jan-04
0323F.1-2a	31	10811	348.72	0.000	0.1335	20	0.4763	149	8.767	312	0.1264	31	117	2145 26	17-Jan-04
0323F.1-2b	*24*	*9064*	*376.80*	1.739	0.1250	52	*0.4658*	*173*	*8.027*	*456*	*0.1347*	*32*	*122*	2028 74	17-Jan-04
Not used (high common Pb)															
0324G.1-1b	*191*	*803*	*4.20*	2.041	0.1446	33	*0.3840*	*80*	*7.654*	*240*	*0.1222*	*37*	*92*	2283 39	17-Jan-04
0324J.3-1b	*29*	*10000*	*346.25*	2.048	0.1798	62	*0.4104*	*163*	*10.171*	*549*	*0.1225*	*29*	*84*	2651 57	17-Jan-04
0324C.1-3b	*20*	*7581*	*386.21*	2.193	0.2013	84	*0.4250*	*173*	*11.795*	*700*	*0.1143*	*28*	*80*	2837 68	17-Jan-04
0324H.1-1b	*32*	*11130*	*343.63*	2.331	0.1539	71	*0.4269*	*167*	*9.056*	*557*	*0.1108*	*27*	*96*	2389 79	17-Jan-04
0308L.1-2a	23	9984	427.04	2.388	0.2069	58	0.4366	161	12.454	601	0.1115	29	81	2881 46	16-Oct-03
0324J.1-2b	*25*	*8554*	*336.57*	2.408	0.1564	75	*0.4313*	*144*	*9.303*	*544*	*0.1318*	*31*	*96*	2418 81	17-Jan-04
0324J.1-2a	24	9274	381.95	2.505	0.1638	90	0.4018	195	9.076	697	0.1164	27	87	2495 93	25-Oct-03
0324J.1-1a	24	10052	423.89	2.540	0.1731	84	0.4059	169	9.686	647	0.1181	27	85	2588 81	25-Oct-03
0308K.1-1a	22	9240	426.72	2.667	0.1607	56	0.3862	119	8.555	411	0.1138	29	85	2463 59	16-Oct-03
0324H.1-2a	19	9985	521.64	2.737	0.1452	118	0.4141	220	8.292	836	0.1277	31	97	2291 140	25-Oct-03
0323B.2-1a	259	2776	10.72	2.755	0.1449	46	0.4141	133	8.273	382	0.0970	27	98	2287 55	17-Jan-04
0323B.1-1a	365	2398	6.57	2.920	0.1513	20	0.4351	82	9.080	216	0.1193	34	99	2361 22	16-Oct-03
0308L.1-4a	327	912	2.79	2.986	0.1343	69	0.4763	163	8.818	544	0.1226	30	117	2155 90	17-Jan-04
0308A.1-2a	398	3347	8.41	3.094	0.1514	16	0.4090	73	8.540	185	0.1115	31	94	2362 19	16-Oct-03
0324G.1-3b	*263*	*2512*	*9.56*	3.111	0.1572	34	*0.3607*	*87*	*7.816*	*259*	*0.1060*	*33*	*82*	2425 36	17-Jan-04
0324C.2-1a	28	13801	484.91	3.129	0.2450	104	0.4305	209	14.539	986	0.1188	27	73	3152 68	25-Oct-03
0308H.1-4b	*644*	*7379*	*11.47*	3.131	0.1527	35	*0.4128*	*102*	*8.688*	*302*	*0.0909*	*30*	*94*	2376 40	17-Jan-04
0324B.2-2a	20	10081	504.76	3.295	0.1716	110	0.4055	187	9.591	791	0.1166	27	85	2573 107	25-Oct-03
0324G.1-3a	200	3168	15.82	3.336	0.1478	28	0.4029	74	8.211	222	0.1042	32	94	2321 33	17-Jan-04
0324G.1-2b	*944*	*894*	*0.95*	3.490	0.1351	30	*0.3435*	*87*	*6.396*	*219*	*0.1038*	*39*	*88*	2165 39	17-Jan-04
0324G.1-4b	*232*	*392*	*1.69*	3.527	0.1452	32	*0.4050*	*95*	*8.106*	*266*	*0.1032*	*54*	*96*	2290 38	17-Jan-04
0324G.1-1a	219	1030	4.71	3.559	0.1376	44	0.3877	79	7.352	288	0.1141	37	96	2197 55	25-Oct-03
0323I.1-1a	179	5582	31.11	3.580	0.1449	25	0.3781	72	7.557	202	0.1107	29	90	2287 30	16-Oct-03
0308H.1-1b	*279*	*1168*	*4.19*	3.730	0.1269	41	*0.3347*	*78*	*5.856*	*234*	*0.1006*	*30*	*91*	2055 57	17-Jan-04
0324J.2-1b	*26*	*9241*	*353.25*	3.760	0.1989	106	*0.3869*	*167*	*10.613*	*738*	*0.1263*	*30*	*75*	2817 87	17-Jan-04
0324D.1-1a	25	14570	582.51	4.602	0.1700	109	0.3820	163	8.956	717	0.1129	26	82	2558 107	25-Oct-03
0323F.1-2a	78	15328	197.54	4.974	0.1379	48	0.3808	88	7.240	307	0.1200	31	94	2201 60	16-Oct-03
0324C.1-2a	45	13890	306.60	5.196	0.1413	91	0.4358	148	8.487	614	0.1170	28	104	2243 111	17-Jan-04
0323A.1-1a	21	11818	570.40	5.528	0.2033	93	0.4283	146	12.006	699	0.1201	31	81	2853 74	16-Oct-03
0324D.1-1b	29	12524	436.11	6.156	0.4319	166	0.4805	203	28.611	1679	0.1127	28	63	4024 58	17-Jan-04

0324F.1-1a	49	13041	267.56	6.348	0.1316	167	0.4391	149	7.969	1010	0.1015	24	111	2120	224	17-Jan-04
0324C.1-2b	*30*	*10966*	*370.85*	6.879	0.4779	162	*0.4863*	*201*	*32.039*	*1763*	*0.1092*	*27*	*61*	4174	50	17-Jan-04
0324D.1-1a	24	11305	475.34	7.037	0.2624	127	0.4558	171	16.488	1025	0.1084	26	74	3261	77	17-Jan-04
0324C.1-3a	21	8317	388.35	7.618	0.2092	163	0.4836	189	13.948	1202	0.1176	28	88	2899	127	17-Jan-04
0323G.1-1a	24	10969	466.04	8.172	0.1497	100	0.4418	137	9.118	670	0.1198	31	101	2342	114	16-Oct-03
0324J.1-1a	43	10570	247.37	9.202	0.2090	133	0.3881	151	11.184	834	0.1126	27	73	2898	103	17-Jan-04
0324I.1-1	27	7682	288.87	29.632	0.1484	538	0.1820	139	3.724	1386	0.0565	14	46	2328	661	25-Oct-03
0324I.1-1a	28	4470	157.86	50.454	0.0477	587	0.2244	145	1.477	1688	0.0633	18	1500	871652		17-Jan-04
0324C.1-1	25	9934	400.75	54.149	0.1537	504	0.4999	304	10.597	3546	0.1191	27	109	2388	588	25-Oct-03

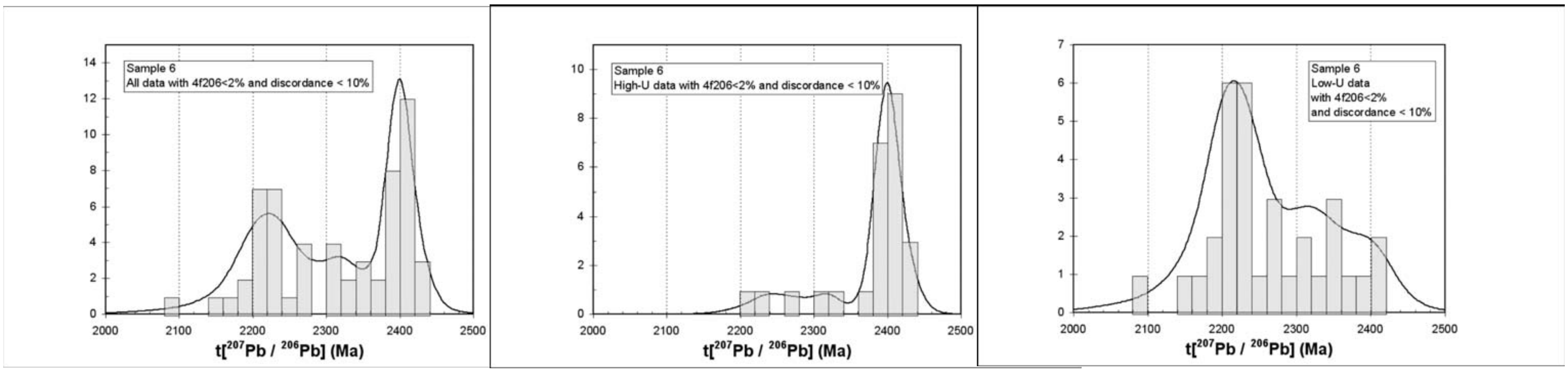

Fig. DR6. Distribution of SHRIMP $^{207}Pb/^{206}Pb$ dates for monazite of different minor element composition from Sample 6, Mount Tom Price iron-ore deposit.

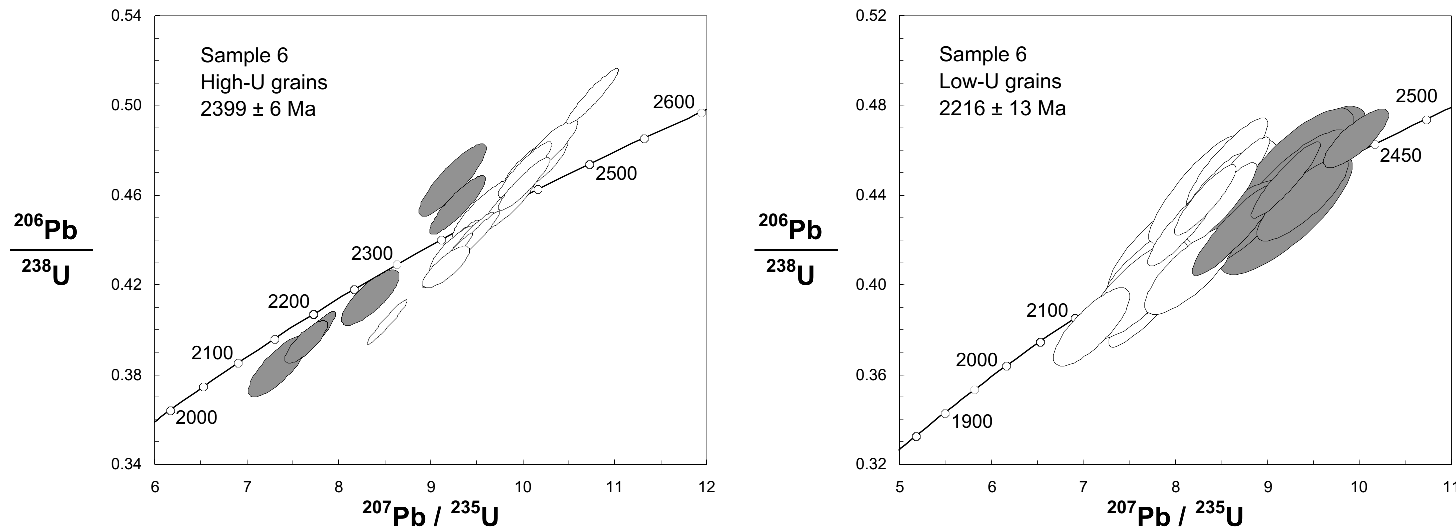

Fig. DR7. SHRIMP U–Pb data for the two chemical groups of monazite from Sample 6, Mount Tom Price iron-ore deposit.

Sample 7

Sample details
Sample 7 is a black shale belonging to the Jeerinah Formation intersected in drill-hole WRL-1 (Fig. 1) from depths of 684.1 m and 695.35 m. The sample contains unusually large patches (up to 100 μm) of inclusion-free monazite.

Analytical notes
These data are from a single large grain from a new mount, taken to confirm the correspondence of new data with those previously published for this sample (2192 ± 5 Ma; Rasmussen et al., 2001).

Interpretation
The data agree with the published data, giving a weighted mean $^{207}Pb/^{206}Pb$ age of 2195 ± 13 Ma (n = 13; MSWD = 1.6; one discordant point omitted). Combining the data with all the original data and re-calculating a weighted mean $^{207}Pb/^{206}Pb$ age gives 2194.0 ± 3.9 Ma (MSWD = 1.4; n = 50).

Date
Monazite growth is confirmed to have occurred at 2194 ± 7 Ma. The ± 10 Ma uncertainty is applied because all data contributing to the averaged age are from two analytical sessions (see above).

TABLE DR7. SHRIMP DATA FOR MONAZITE IN SAMPLE 7, WRL-1

Analysis	U (ppm)	Th (ppm)	Th/U	f206 (%)	$^{207}Pb^*/^{206}Pb^*$	±	$^{206}Pb^*/^{238}U$	±	$^{207}Pb^*/^{235}U$	±	$^{208}Pb^*/^{232}Th$	±	conc. (%)	$^{207}Pb^*/^{206}Pb^*$ Age (Ma)	±	Date
0419F.1-1	46	242	5.22	0.066	0.1361	20	0.3941	111	7.395	244	0.1145	34	98	2178	26	28-Mar-04
0419F.1-2	64	187	2.90	0.000	0.1393	15	0.4134	101	7.943	218	0.1172	37	101	2219	19	28-Mar-04
0419F.1-3	69	197	2.86	0.301	0.1344	17	0.4019	102	7.447	217	0.1161	37	101	2156	21	28-Mar-04
0419F.1-4	78	309	3.98	0.058	0.1371	20	0.4246	111	8.029	247	0.1163	34	104	2192	25	28-Mar-04
0419F.2-1	47	425	9.15	0.000	0.1369	18	0.4114	116	7.765	250	0.1153	30	102	2188	23	28-Mar-04
0419F.2-2	115	383	3.34	0.053	0.1371	14	0.4124	99	7.794	210	0.1152	31	102	2190	18	28-Mar-04
0419F.2-3	105	28	0.27	0.060	0.1357	18	0.4219	104	7.896	229	0.1219	80	104	2174	23	28-Mar-04
0419F.2-4	88	37	0.42	0.000	0.1371	13	0.4201	97	7.944	204	0.1236	76	103	2191	17	28-Mar-04
0419F.2-5	89	53	0.60	0.030	0.1388	15	0.4001	97	7.655	209	0.1218	60	98	2212	19	28-Mar-04
0419F.3-1	98	119	1.22	0.031	0.1410	19	0.4201	115	8.166	257	0.1205	47	101	2239	23	28-Mar-04
0419F.3-2	153	700	4.58	0.000	0.1399	12	0.4333	97	8.360	206	0.1307	33	104	2226	14	28-Mar-04
0419F.3-3	191	462	2.42	0.019	0.1359	9	0.4424	92	8.289	188	0.1357	36	109	2175	12	28-Mar-04
0419F.3-5	199	996	5.00	0.000	0.1374	10	0.4328	91	8.198	189	0.1373	32	106	2194	13	28-Mar-04
Not used (discordant)																
0419F.3-4	204	324	1.59	0.093	0.1376	14	0.4663	101	8.846	218	0.1458	44	112	2197	17	28-Mar-04

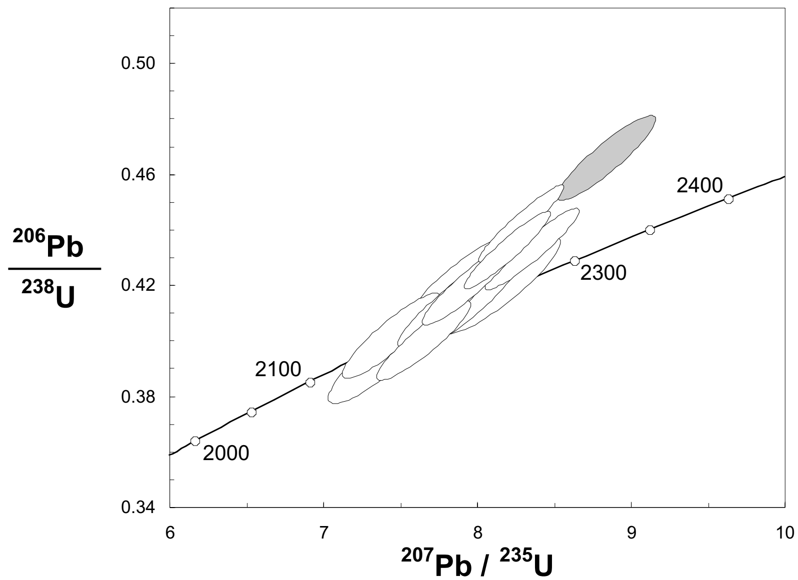

Fig. DR8. SHRIMP U–Pb concordia plot for monazite from Sample 7, WRL-1.

Sample 8

Sample details

Sample 8 contains coarse, inclusion-rich metamorphic xenotime crystals in black shale of the Mt Roe Basalt (Fortescue Group) intersected in drill-hole ABDP-6 (Fig. 1) from a depth of 135 m.

Analytical notes

Data were collected from two mounts in two analytical sessions. The $^{208}Pb/^{232}Th$ data are not reported for the first session because they were clearly aberrant, though the reason for this has not been identified.

Interpretation

The majority of data are concordant within 5% and have low common Pb (4f206<1%). Since there are ample data, those outside these limits have not been considered in the age interpretation. In addition, two analyses of relatively poor precision have been disregarded, though they are entirely consistent with other data. Two analyses from one grain are distinct young outliers.

As with the monazite in Sample 6, there are two distinct peaks in the $^{207}Pb/^{206}Pb$ distribution (Fig. DR9), but in this case there is no apparent correlation with U-Th composition. Clearly, some of the data between the peaks are likely to represent analyses of mixtures of intergrown or overgrown xenotime of at least two ages. The simplest interpretation is that there were only two episodes of xenotime growth, and consequently that the oldest and youngest self-consistent data subsets best define the times of growth. If there were other discrete events it is impossible to discern them in these data.

The oldest eight $^{207}Pb/^{206}Pb$ dates, from five grains, have a weighted mean of 2432 ± 14 Ma (MSWD = 2.0). The youngest subset (omitting the two outliers) is considerably larger (n = 28) and gives 2178.8 ± 6.7 Ma (MSWD = 1.7).

Dates

The two dominant episodes of xenotime growth occurred at 2432 ± 14 Ma and 2179 ± 7 Ma. Note, however, that the real uncertainies are larger than these statistical limits because of the extent of data selection applied.

TABLE DR8. SHRIMP DATA FOR XENOTIME IN SAMPLE 8, ABDP-6

Analysis	U (ppm)	Th (ppm)	Th/U	f206 (%)	$^{207}Pb^*/^{206}Pb^*$	±	$^{206}Pb^*/^{238}U$	±	$^{207}Pb^*/^{235}U$	±	$^{208}Pb^*/^{232}Th$	±	conc. (%)	$^{207}Pb^*/^{206}Pb^*$ Age (Ma)	±	Date
Older group																
0418D.1-4	610	1112	1.82	0.365	0.1604	27	0.4604	87	10.184	262			99	2460	29	27-Mar-04
0418F.1-6	762	294	0.40	-0.015	0.1592	6	0.4715	77	10.348	174	0.1203	35	102	2447	6	9-Apr-04
0409H.1-2	640	1201	1.94	0.650	0.1580	15	0.4612	77	10.044	195	0.0974	18	100	2434	16	9-Apr-04
0418F.1-5	921	582	0.65	0.147	0.1576	9	0.4590	75	9.976	173	0.1127	28	100	2430	9	9-Apr-04
0418E.1-3	338	106	0.31	0.427	0.1562	12	0.4554	99	9.809	229			100	2415	13	27-Mar-04
0418A.1-2	453	1007	2.22	0.513	0.1560	12	0.4420	88	9.507	204			98	2413	13	27-Mar-04
0418A.1-3	529	1382	2.61	0.266	0.1560	11	0.4514	86	9.709	197			100	2412	12	27-Mar-04
0409A.1-3	361	291	0.83	0.328	0.1548	29	0.4495	80	9.597	252	0.0746	209	100	2400	32	9-Apr-04
Probably mixture ages																
0418E.1-4	406	206	0.51	0.136	0.1542	10	0.4212	86	8.957	192			95	2393	11	27-Mar-04
0409C.1-2	676	991	1.51	0.535	0.1528	23	0.4553	84	9.593	232	0.1123	74	102	2377	26	9-Apr-04
0418C.1-4	932	1481	1.59	0.223	0.1528	7	0.4316	72	9.091	158			97	2377	8	27-Mar-04
0418D.1-8	795	1882	2.45	0.330	0.1506	16	0.4556	76	9.460	189	0.1174	45	103	2353	18	9-Apr-04
0418E.1-9	565	811	1.48	0.162	0.1499	11	0.4486	78	9.271	175	0.1235	59	102	2345	12	9-Apr-04
0409A.1-2	1214	4285	3.65	0.488	0.1468	13	0.4262	77	8.627	176	0.0910	21	99	2309	16	9-Apr-04
0418A.1-4	483	1643	3.40	0.204	0.1416	9	0.3914	75	7.644	154			95	2247	10	27-Mar-04
0418C.1-6	444	486	1.13	0.131	0.1408	10	0.4012	77	7.787	160	0.1015	34	97	2237	13	9-Apr-04
0418E.1-13	281	88	0.32	-0.183	0.1402	13	0.3991	80	7.713	171	0.1081	41	97	2229	16	9-Apr-04
0418C.1-5	492	475	1.00	-0.320	0.1394	9	0.3863	77	7.426	157	0.0987	67	95	2220	11	9-Apr-04
0418D.1-2	495	537	1.08	0.492	0.1391	28	0.4233	81	8.119	228			103	2216	34	27-Mar-04
Younger group																
0418D.1-7	575	353	0.63	0.074	0.1386	13	0.3889	81	7.433	171	0.1051	29	96	2210	17	9-Apr-04
0418D.1-6	503	1293	2.66	0.156	0.1385	12	0.3835	67	7.327	145	0.0974	31	95	2209	15	9-Apr-04
0409B.1-1	442	712	1.66	-0.161	0.1385	10	0.3982	70	7.602	144	0.0974	53	98	2208	12	9-Apr-04
0409E.1-2	1081	3118	2.98	0.117	0.1374	8	0.4084	66	7.738	134	0.0935	99	101	2195	11	9-Apr-04
0409C.1-1	741	958	1.34	0.371	0.1373	12	0.3972	76	7.520	159	0.0991	67	98	2194	15	9-Apr-04
0409C.1-4	597	752	1.30	0.024	0.1373	11	0.4047	67	7.660	142	0.1060	52	100	2193	14	9-Apr-04
0418F.1-4	807	388	0.50	0.101	0.1372	15	0.4177	72	7.903	163	0.1066	38	103	2193	19	9-Apr-04
0409E.1-3	870	1514	1.80	0.038	0.1372	15	0.4080	67	7.718	156	0.1040	41	101	2192	20	9-Apr-04
0409C.1-3	586	636	1.12	0.069	0.1369	9	0.4049	67	7.644	137	0.1011	19	100	2189	11	9-Apr-04
0418A.1-5	471	3117	6.84	0.713	0.1368	22	0.3895	72	7.347	185	0.0948	22	97	2187	28	9-Apr-04
0418F.1-1	1136	1344	1.18	0.021	0.1367	5	0.3824	60	7.209	116			96	2186	6	27-Mar-04
0418G.1-1	1329	112	0.08	0.158	0.1366	9	0.4049	63	7.623	128			100	2184	11	27-Mar-04
0418C.1-2	469	1073	2.29	0.111	0.1358	8	0.4020	97	7.528	188			100	2174	10	27-Mar-04

0418D.1-1	478	273	0.57	0.498	0.1357	18	0.4085	80	7.645	185			102	2173	24	27-Mar-04
0418E.1-5	354	260	0.74	0.277	0.1357	12	0.3984	84	7.453	171			99	2173	15	27-Mar-04
0418D.1-3	624	311	0.50	0.165	0.1357	8	0.4117	94	7.700	182			102	2172	10	27-Mar-04
0409H.1-1	616	2183	3.66	0.437	0.1355	15	0.3799	64	7.099	144	0.0813	23	96	2171	19	9-Apr-04
0418E.1-14	325	144	0.46	0.055	0.1355	25	0.3920	74	7.325	197	0.1004	57	98	2171	32	9-Apr-04
0418D.1-5	548	1068	1.95	0.637	0.1354	21	0.3924	74	7.327	182			98	2169	27	27-Mar-04
0409B.1-3	639	1463	2.37	-0.100	0.1353	7	0.3891	64	7.259	125	0.0990	19	98	2168	8	9-Apr-04
0418H.1-1	513	1726	3.36	0.064	0.1348	7	0.3733	68	6.936	131			95	2161	9	27-Mar-04
0409E.1-1	776	522	0.70	0.608	0.1344	24	0.3979	72	7.373	189	0.0779	53	100	2156	31	9-Apr-04
0418C.1-7	510	2172	4.40	0.005	0.1343	9	0.3982	70	7.375	140	0.1024	28	100	2155	12	9-Apr-04
0418B.1-4	348	1328	3.94	0.154	0.1336	15	0.3837	87	7.068	179	0.0965	33	98	2146	19	9-Apr-04
0418C.1-8	620	1665	2.77	0.279	0.1335	17	0.3928	85	7.232	184	0.0909	95	100	2145	22	9-Apr-04
0418A.1-6	661	3837	6.00	0.781	0.1334	24	0.4039	71	7.427	189	0.1039	23	102	2143	31	9-Apr-04
0409B.1-4	657	3008	4.73	0.331	0.1332	16	0.3842	64	7.057	147	0.0928	25	98	2141	21	9-Apr-04
0418C.1-3	470	732	1.56	0.540	0.1331	17	0.3706	95	6.802	196			95	2139	22	27-Mar-04
Young outliers																
0418B.1-5	370	2163	6.03	0.425	0.1275	23	0.3686	70	6.481	174	0.0879	18	98	2064	32	9-Apr-04
0418B.1-3	407	2617	6.43	0.563	0.1264	28	0.3807	77	6.635	201			102	2048	39	27-Mar-04
Discordant (>5%)																
0418E.1-9	336	133	0.40	0.047	0.1616	10	0.4299	95	9.582	220			93	2473	10	27-Mar-04
0418A.1-7	359	311	0.89	0.006	0.1570	20	0.4979	97	10.778	256	0.1121	50	107	2424	22	9-Apr-04
0418F.1-2	1064	320	0.30	0.665	0.1557	23	0.4906	95	10.535	260			107	2410	25	27-Mar-04
0409A.1-1	928	2159	2.41	0.232	0.1503	10	0.3974	68	8.236	153	0.0800	20	92	2349	12	9-Apr-04
0418G.1-2	1253	254	0.20	0.020	0.1383	5	0.3738	58	7.130	114			93	2207	6	27-Mar-04
0418C.1-1	264	47	0.18	0.130	0.1375	10	0.3796	87	7.199	175			94	2196	13	27-Mar-04
0418E.1-8	410	248	0.61	0.353	0.1374	11	0.4338	89	8.215	183			106	2194	14	27-Mar-04
0418F.1-3	1084	194	0.18	0.163	0.1373	9	0.4344	71	8.223	145	0.1220	55	106	2194	11	9-Apr-04
0418E.1-7	325	327	1.01	0.086	0.1369	9	0.3707	80	6.998	159			93	2188	12	27-Mar-04
0418E.1-1	496	451	0.91	0.396	0.1366	12	0.4488	89	8.456	183			109	2185	15	27-Mar-04
0418E.1-6	254	83	0.33	0.209	0.1347	12	0.3603	87	6.691	172			92	2160	15	27-Mar-04
Poor precision																
0418E.1-2	318	239	0.75	0.398	0.1623	69	0.4196	95	9.389	464			91	2479	72	27-Mar-04
0418E.1-12	857	2410	2.91	0.317	0.1835	183	0.5773	123	14.607	1557	0.1722	64	109	2685	165	9-Apr-04
Higher common Pb (4f206 > 1%)																
0418E.1-10	596	504	0.87	1.057	0.1431	29	0.4567	88	9.013	255	0.1250	56	107	2266	34	9-Apr-04
0418B.1-6	403	2151	5.52	1.063	0.1318	40	0.3751	83	6.818	263	0.0985	46	97	2123	53	9-Apr-04
0409B.1-2	406	1786	4.54	1.105	0.1326	34	0.3922	70	7.171	230	0.0990	23	100	2133	45	9-Apr-04
0418B.1-1	346	778	2.25	1.123	0.1339	40	0.3986	86	7.357	274			101	2149	52	27-Mar-04
0418E.1-11	469	255	0.56	1.261	0.1385	29	0.4476	83	8.546	244	0.1135	59	108	2208	36	9-Apr-04

0418D.1-9	384	176	0.47	1.641	0.1543	53	0.4698	101	9.998	415	0.1087	177	104	2395	58	9-Apr-04
0418A.1-1	459	2035	4.43	1.664	0.1338	59	0.3887	82	7.169	356			99	2148	76	27-Mar-04
0418B.1-2	279	1010	3.62	2.532	0.1438	51	0.4102	98	8.132	352			97	2273	61	27-Mar-04

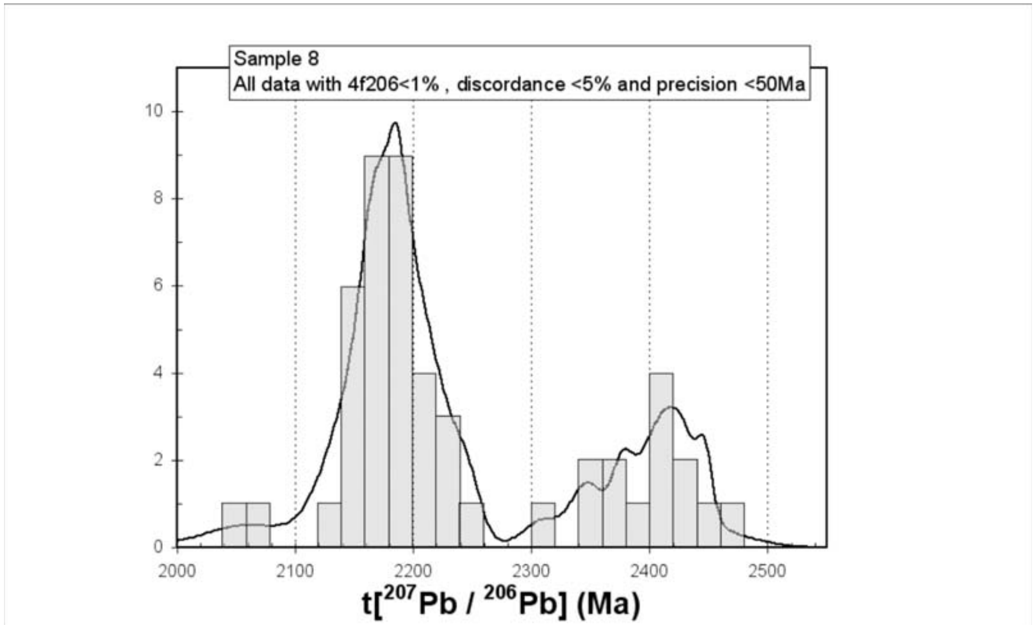

Fig. DR9. SHRIMP $^{207}Pb/^{206}Pb$ dates for xenotime from Sample 8, ABDP-6. Data with 4f206 >1% or discordance >5%, and two points with poor precision, are not plotted.

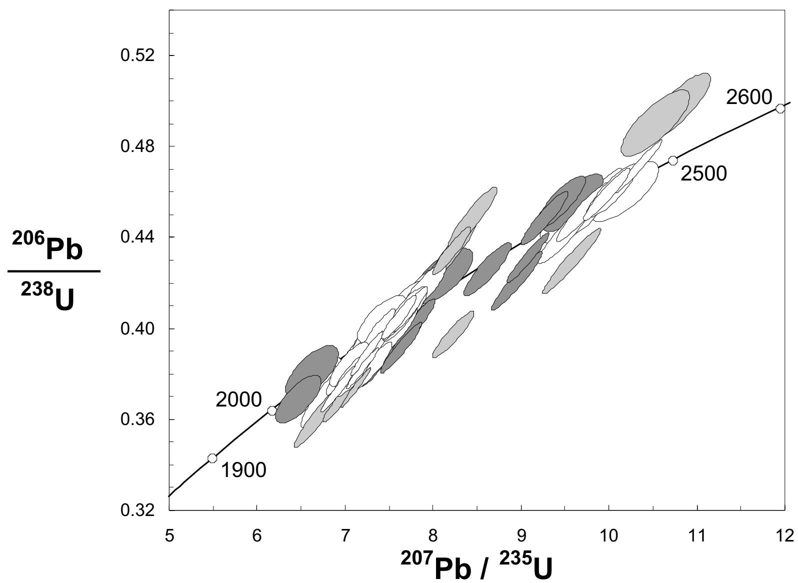

Fig. DR10. SHRIMP U–Pb concordia plot for xenotime from Sample 8, ABDP-6. Data with 4f206 >1% or discordance >5%, and two points with poor precision, are not plotted.

Sample 9

Sample details

Sample 9 is a black shale belonging to the Jeerinah Formation intersected in drill-hole DDH-186 (Fig. 1) from a depth of 163.0 m and 173.0 m. The sample contains coarse, inclusion-rich monazite crystals and unusually large xenotime overgrowths that surround detrital zircon grains.

Analytical notes

The first monazite data for this sample (mount A-55, August 2000) are limited by having no concurrent data for secondary standards. A second data set (mount 04-58, July 2004) was of dubious quality because the secondary standards required a renormalisation of $^{207}Pb/^{206}Pb$ corresponding to ~20 Ma, about twice as large as the usual maximum correction. There is no identified systematic defect that could cause such an unusually large aberration, but it suggests that the data are unreliable. After applying the renormalisation, these data give a mean $^{207}Pb/^{206}Pb$ age (2402 ± 7 Ma) that is inconsistent with (younger than) the earlier data (2417 ± 7 Ma), that is, it is possible that they have been overcorrected. A second session on mount A-55 was initiated to resolve the disparity between data sets. This session was truncated by instrument problems, so does not give a highly precise date (2416 ± 12 Ma), but it supports the original data from mount A-55.

The xenotime data are from the only four grains, analysed in a single session (mount 04-09).

Interpretation

The monazite data from the second analytical session on mount A-55 are considered the most reliable, and are used in preference to those in the larger, but less controlled, data sets. The xenotime data are consistent with this result, but there is significant scatter in the data and the result is not sufficiently precise to improve the age by combination with the monazite result. Two analyses from one xenotime grain suggest the existence of a younger xenotime component.

Date

The age of hydrothermal monazite and xenotime formation is considered to be 2416 ± 12 Ma, though more data are required (if more xenotime can be identified) to fully determine the detailed timing relationships.

TABLE DR9. SHRIMP DATA FOR MONAZITE IN SAMPLE 9, DDH-186

Analysis	U (ppm)	Th (ppm)	Th/U	f206 (%)	$^{207}Pb^*/^{206}Pb^*$	±	$^{206}Pb^*/^{238}U$	±	$^{207}Pb^*/^{235}U$	±	$^{208}Pb^*/^{232}Th$	±	conc. (%)	$^{207}Pb^*/^{206}Pb^*$ Age (Ma)	±	Date
A55.B1-3a	308	1281	4.16	0.243	0.1551	15	0.4519	172	9.666	391	0.1236	51	100	2403	16	2-Nov-04
A55.A1-1a	256	1039	4.06	0.073	0.1554	17	0.4679	186	10.027	426	0.1424	59	103	2407	19	2-Nov-04
A55.A1-2a	346	745	2.15	0.026	0.1562	15	0.4894	183	10.543	420	0.1558	61	106	2415	16	2-Nov-04
A55.A1-3a	505	701	1.39	0.015	0.1565	10	0.4841	182	10.450	407	0.1474	72	105	2419	11	2-Nov-04
A55.A1-4a	175	2380	13.60	0.160	0.1568	18	0.4324	169	9.347	393	0.1283	47	96	2421	19	2-Nov-04
A55.B1-1a	111	166	1.49	0.000	0.1578	18	0.4304	180	9.365	419	0.1215	54	95	2432	19	2-Nov-04
Discordant																
A55.B1-2a	90	1064	11.80	0.000	0.1551	20	0.3809	174	8.147	399	0.1188	48	87	2403	22	2-Nov-04

TABLE DR10. SHRIMP DATA FOR XENOTIME IN SAMPLE 9, DDH-186

Analysis	U (ppm)	Th (ppm)	Th/U	f206 (%)	$^{207}Pb^*/^{206}Pb^*$	±	$^{206}Pb^*/^{238}U$	±	$^{207}Pb^*/^{235}U$	±	$^{208}Pb^*/^{232}Th$	±	conc. (%)	$^{207}Pb^*/^{206}Pb^*$ Age (Ma)	±	Date
0409D.1-1	492	4506	9.47	0.084	0.1560	10	0.4692	82	10.090	189	0.1202	21	103	2412	11	9-Apr-04
0409D.1-1b	*396*	*3749*	*9.79*	-0.003	0.1556	8	*0.4399*	*79*	*9.438*	*177*	*0.1144*	*22*	*98*	2408	9	9-Apr-04
0409D.1-3a	516	1435	2.87	-0.039	0.1583	7	0.4884	85	10.658	192	0.1207	44	105	2437	8	9-Apr-04
0409D.1-3b	*565*	*1311*	*2.40*	-0.002	0.1596	8	*0.4571*	*80*	*10.058*	*183*	*0.1219*	*67*	*99*	2451	8	9-Apr-04
0409D.1-4a	695	362	0.54	0.287	0.1560	11	0.5022	85	10.804	199	0.1074	72	109	2413	12	9-Apr-04
0409D.1-4b	*970*	*907*	*0.97*	0.082	0.1584	8	*0.4642*	*76*	*10.136*	*174*	*0.1080*	*100*	*101*	2438	8	9-Apr-04
Possible young outliers																
0409D.1-2a	132	680	5.32	0.687	0.1482	32	0.4366	95	8.920	280	0.1093	27	100	2325	37	9-Apr-04
0409D.1-2b	*136*	*865*	*6.57*	0.851	0.1472	37	*0.4001*	*90*	*8.120*	*277*	*0.1039*	*51*	*94*	2314	43	9-Apr-04

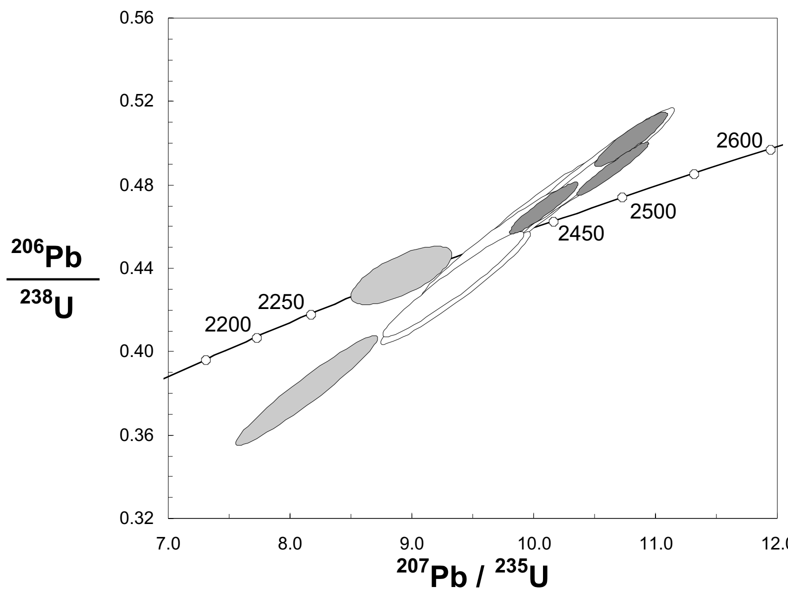

Fig. DR11. SHRIMP U–Pb data for monazite (white) and xenotime (dark grey) from Sample 9, DDH-186. One discordant monazite point and one young xenotime outlier are light shaded.

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