

Re-evaluation of contact relationships between Ordovician volcanic belts and the quartz-rich turbidites of the Lachlan Orogen*

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SUPPLEMENTARY PAPERS

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* Appendix 1 and Table 2 [indicated by an asterisk (*) in the text and listed at the end of the paper] are Supplementary Papers; copies may be obtained from the Geological Society of Australia's website (www.gsa.org.au) or from the National Library of Australia's Pandora archive (<http://nla.gov.au/nla.arc-25194>).

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APPENDIX 1 ANALYTICAL DETAILS

Table 2 Zircon geochronology for sandstones from the quartz rich and volcanoclastic sandstone. Analyses in italics denote analyses with Pb loss or other problems. The ICPMS measurements were collected over a three-year period during which precision of the measurement improved. However, this should not affect the accuracy of the data.

APPENDIX 1: ANALYTICAL DETAILS

The LA-ICPMS method is now widely used for measuring U, Th and Pb isotopic data (e.g. Fryer et al. 1993; Compston 1999; Black et al. 2003; Black et al. 2004; Harris et al. 2004). At the University of Tasmania we worked on an HP4500 quadrupole ICPMS with a 213 nm New Wave Laser using the following method:

Between 100 to 200 g of rock from each sample was repeatedly sieved and crushed to a grain size of <180 micron. Crushing was performed in a mortar and pestle or a Cr-steel ring mill depending on sample hardness. Heavy minerals were then separated using a combination of a mechanised panning device (superpan) and a hand pan. The heavy mineral residue was then dried. Magnetic and paramagnetic minerals were separated using a hand magnet and a Franz magnetic separator. Between 20 to 60 zircons were picked from the non-magnetic heavy mineral separate using a single hair from a fine artist's paint brush, and mounted on double sided sticky tape. Epoxy glue was then poured into a 2.5 cm diameter mould on top of the zircons. The mount was dried for 12 hours and polished using clean sandpaper and a clean polishing lap. The samples were then washed in distilled water in an ultrasonic bath.

Analyses were performed two hours after ignition of the mass spectrometer to enable the machine to stabilise. Four primary (Temora standard of Black et al. 2003) and two secondary standards (91500 standard of Wiendenbeck et al. 1995) were analysed at the beginning of the session and every 12 unknown zircons (roughly every hour). The Mudgee and Lyndhurst analyses used zircons from the 411 Ma Blind Gabbro (Bill Collins pers com. 2001) instead of the Temora standard. Each analysis began with a 30 second blank gas measurement followed by a further 30 seconds of analysis time when the laser was switched on. Zircons were sampled on 30 micron spots using the laser at 5 Hz and a density of approximately 12 mJ/cm². A flow of He carrier gas at a rate of 0.7 litres/minute carried particles ablated by the laser out of the chamber to be mixed with Ar gas and carried to the plasma torch. Elements measured include ⁹⁶Zr, ¹⁴⁶Nd, ¹⁷⁸Hf, ²⁰²Hg, ²⁰⁴Pb, ²⁰⁶Pb, ²⁰⁷Pb, ²⁰⁸Pb, ²³²Th and ²³⁸U with each element being measured sequentially every 0.2 s.

The data reduction method used was based on the method outlined in detail by Harris et al. (2004), modified to suit the ICPMS and laser at the University of Tasmania. The average of the background count rates were subtracted from each isotope. Pb and U isotopic ratios were then calculated for each 0.2 s measurement. These ratios were filtered to exclude the top and bottom 1% to eliminate spikes and spurious data. Filtered ratios were then corrected for machine drift, downhole fractionation and mass bias. The machine drift correction was calculated by fitting a line to the primary standard data measured every 12 analysis throughout the day. Machine drift was also checked by examining the secondary standard data. The downhole fractionation and mass bias correction factors were calculated by averaging the drift corrected ratios on each 0.2 s primary standard measurements (relative to the start of the analysis), fitting a line to the data and then dividing it by the recommended value for the primary standard. A set of correction factors was generated for each 0.2 s intervals and for each isotopic ratio.

After the corrections were applied to the ratios, radiometric ages were calculated for each 0.2 s measurement and the age data for each analysis was plotted against the analysis time. An integration interval was then chosen for the most stable portion of the analysis, to exclude parts with contamination from inclusions. The standard errors quoted were based on the standard error of the measurements within the integration intervals and the errors on the measurement of the standards.

Element abundances were calculated using the method outlined by Kosler (2001) using Zr as the internal standard element, assuming stoichiometric proportions and using the secondary standard 91500 to correct for mass bias.

Table 2 Zircon geochronology for sandstones from the quartz rich and volcanoclastic sandstone. Analyses in italics denote analyses with Pb loss or other problems. The ICPMS measurements were collected over a three year period during which precision of the measurement improved. However, this should not affect the accuracy of the data.

Sample: BLRS0096, Adaminaby Group south of Lyndhurst, (GR 694240 6265690) (ICPMS)

analysis	$^{206}\text{Pb}/^{238}\text{U}$	Std Er	$^{207}\text{Pb}/^{206}\text{Pb}$	Std Er	$^{206}\text{Pb}/^{238}\text{U}$ age	Std Er
01Ja15e06	0.0775	2.1%	0.0611	2.7%	481	10
01Ja15e07	0.0775	1.5%	0.0868	2.0%	481	7
01Ja15d14	0.0788	1.3%	0.0589	2.4%	489	6
01Ja15d11	0.0806	1.5%	0.0783	1.8%	500	8
01Ja15e05	0.0806	1.6%	0.0589	2.5%	500	8
01Ja15e14	0.0821	1.4%	0.0578	2.6%	509	7
01Ja15d07	0.0853	1.4%	0.0573	2.9%	528	7
01Ja15e11	0.0869	1.5%	0.0685	2.1%	537	8
01Ja15e08	0.0893	1.4%	0.1267	3.4%	551	7
01Ja15d16	0.0939	1.5%	0.0549	3.3%	579	9
01Ja15e15	0.0947	1.5%	0.0660	2.4%	583	9
01Ja15d05	0.0953	1.3%	0.0583	2.0%	587	8
01Ja15e16	0.1194	1.8%	0.3135	3.0%	727	13
01Ja15e10	0.1270	1.2%	0.0871	1.3%	771	9
01Ja15e09	0.1359	1.5%	0.0706	1.5%	821	12
01Ja15d12	0.1416	1.4%	0.1004	2.6%	854	12
01Ja15d06	0.1423	1.6%	0.0751	2.5%	858	14
01Ja15d15	0.1682	1.4%	0.0949	1.3%	1002	14
01Ja15d13	0.1708	1.3%	0.0737	1.4%	1017	14
01Ja15e13	0.1903	1.3%	0.0764	1.5%	1123	15
01Ja15e12	0.1986	1.9%	0.0817	1.4%	1168	22
01Ja15d08	0.4180	1.2%	0.1447	1.3%	2251	28
01Ja15d10	0.4212	1.6%	0.1733	1.7%	2266	35

**Sample :BLRS0582 Coobing Formation, Coombing Creek, east of Lyndhurst (694246 6275914)
(SHRIMP)**

analysis	$^{206}\text{Pb}/^{238}\text{U}$	Std Er	$^{207}\text{Pb}/^{206}\text{Pb}$	Std Er	$^{206}\text{Pb}/^{238}\text{U}$ age	Std Er
15.1	0.0720	1.1%	0.0607	1.6%	448	5
16.1	0.0725	1.2%	0.0583	1.1%	451	5
14.1	0.0735	1.4%	0.0698	2.3%	457	7
18.1	0.0737	1.1%	0.0588	1.0%	458	5
9.1	0.0742	1.3%	0.0612	1.9%	461	6
2.1	0.0743	1.0%	0.0583	1.3%	462	4
1.1	0.0744	1.1%	0.0583	1.5%	463	5
3.1	0.0748	1.3%	0.0681	2.0%	465	6
17.1	0.0751	1.3%	0.0645	5.2%	467	6
5.1	0.0753	1.3%	0.0605	1.8%	468	6
13.1	0.0754	1.4%	0.0644	2.2%	469	6
12.1	0.0755	1.2%	0.0610	1.7%	469	6
4.1	0.0757	1.1%	0.0587	1.4%	470	5
6.1	0.0760	1.2%	0.0596	2.1%	472	6
10.1	0.0762	1.1%	0.0598	1.4%	474	5
7.1	0.0763	1.0%	0.0573	1.3%	474	5
19.1	0.0766	1.1%	0.0576	1.4%	476	5
11.1	0.0767	1.1%	0.0570	1.5%	476	5
8.1	0.0775	0.9%	0.0578	0.8%	481	4
20	0.0755	3.9%	0.0635	1.2%	469	18

Sample : OB184 Adaminaby Group, south of Oberon (ICPMS)

analysis	$^{206}\text{Pb}/^{238}\text{U}$	Std Er	$^{207}\text{Pb}/^{206}\text{Pb}$	Std Er	$^{206}\text{Pb}/^{238}\text{U}$ age	Std Er
02No13i12	0.0746	1.7%	0.0542	34%	464	8
02No13k10	0.0761	2.3%	0.0676	18%	473	11
02No13i04	0.0779	1.7%	0.0556	24%	483	8
02No13i03	0.0791	1.6%	0.0690	13%	491	8
02No13d03	0.0797	1.3%	0.0636	13%	494	6
02No13i09	0.0805	1.4%	0.0581	14%	499	7
02No13d05	0.0809	1.5%	0.0604	11%	501	7
02No13k06	0.0814	1.7%	0.0592	20%	504	9
02No13i05	0.0815	1.5%	0.0679	10%	505	8
02No13i08	0.0824	1.7%	0.0556	20%	511	9
02No13i02	0.0836	1.4%	0.0619	14%	518	7
02No13i01	0.0848	1.4%	0.0632	11%	525	8
02No13i07	0.0868	1.6%	0.0723	13%	537	9
02No13d06	0.0877	1.7%	0.0577	30%	542	9
02No13k01	0.0882	1.4%	0.0600	21%	545	8
02No13k07	0.0907	2.1%	0.0588	47%	560	12
02No13d09	0.0932	1.4%	0.0549	20%	575	8
02No13d07	0.0941	1.3%	0.0571	27%	580	8
02No13d02	0.0964	1.1%	0.0657	6%	593	7
02No13k08	0.0977	1.6%	0.0621	11%	601	9
02No13k09	0.1405	1.5%	0.0741	7%	848	13
02No13i10	0.1487	0.9%	0.0763	4%	894	8
02No13i11	0.1826	1.4%	0.0781	6%	1081	15
02No13k02	0.1839	1.6%	0.0778	8%	1088	17
02No13d01	0.1876	1.2%	0.0855	5%	1108	14
02No13k03	0.1930	1.5%	0.0778	7%	1138	17
02No13d10	0.1951	1.1%	0.0845	3%	1149	13
02No13d04	0.2871	1.1%	0.1091	1%	1627	18
02No13k05	0.3031	1.8%	0.1064	4%	1707	32
02No13d08	0.4588	1.1%	0.1806	1%	2434	27
02No13k04	0.6077	1.6%	0.2570	1%	3061	48
<i>02No13i06</i>	<i>0.0671</i>	<i>2.4%</i>	<i>0.0867</i>	<i>5%</i>	<i>419</i>	<i>10</i>
<i>02No13k07</i>	<i>0.0470</i>	<i>1.7%</i>	<i>0.1498</i>	<i>1%</i>	<i>296</i>	<i>5</i>
<i>02No13k11</i>	<i>0.0616</i>	<i>2.0%</i>	<i>0.1121</i>	<i>2%</i>	<i>385</i>	<i>8</i>
<i>02No13d10</i>	<i>0.0631</i>	<i>1.2%</i>	<i>0.0743</i>	<i>4%</i>	<i>394</i>	<i>5</i>

Sample: 99/10/21-2 Cargo Volcanics north east of Cargo, (GR 669750 6311140) (ICPMS).

analysis	$^{206}\text{Pb}/^{238}\text{U}$	Std Er	$^{207}\text{Pb}/^{206}\text{Pb}$	Std Er	$^{206}\text{Pb}/^{238}\text{U}$ age	Std Er
04FE03J10	0.0700	1.3%	0.0580	4%	436	6
04FE03I7	0.0700	1.3%	0.0555	5%	436	5
04FE03J12	0.0703	1.1%	0.0562	3%	438	5
04FE03J5	0.0707	1.6%	0.0521	5%	440	7
04FE03J11	0.0711	1.6%	0.0573	6%	443	7
04FE03J9	0.0711	1.6%	0.0511	6%	443	7
04FE03K8	0.0712	1.5%	0.0570	5%	443	7
04FE03J4	0.0715	1.7%	0.0531	7%	445	7
04FE03J1	0.0719	1.5%	0.0633	5%	448	7
04FE03I1	0.0721	1.3%	0.0569	4%	449	6
04FE03K2	0.0724	1.0%	0.0566	2%	451	5
04FE03I4	0.0724	1.0%	0.0553	3%	451	4
04FE03K7	0.0725	1.5%	0.0557	5%	451	7
04FE03J3	0.0728	1.4%	0.0560	4%	453	7
04FE03K9	0.0731	1.1%	0.0569	3%	455	5
04FE03K5	0.0732	1.2%	0.0571	3%	455	6
04FE03I2	0.0732	1.5%	0.0536	5%	455	7
04FE03I5	0.0732	1.2%	0.0589	4%	455	5
04FE03J7	0.0733	1.5%	0.0611	5%	456	7
04FE03K4	0.0733	1.2%	0.0567	2%	456	5
04FE03K6	0.0736	1.6%	0.0589	5%	458	7
04FE03J2	0.0737	1.3%	0.0550	5%	459	6
04FE03J8	0.0743	1.5%	0.0521	5%	462	7
04FE03K10	0.0743	1.1%	0.0560	2%	462	5
04FE03I10	0.0754	1.2%	0.0573	4%	469	6
04FE03K1	0.0755	1.1%	0.0569	4%	469	5
04FE03I8	0.0762	1.1%	0.0587	3%	473	5
04FE03I3	0.0764	1.6%	0.0555	4%	474	7
04FE03K12	0.0770	1.3%	0.0579	3%	478	6
04FE03K11	0.0774	1.2%	0.0554	2%	481	6
04FE03I12	0.0778	1.2%	0.0553	4%	483	6
04FE03I11	0.0787	1.4%	0.0559	4%	488	7
04FE03K3	0.0788	1.4%	0.0553	4%	489	7
04FE03I6	0.0801	1.4%	0.0566	5%	497	7
04FE03I9	0.0817	1.2%	0.0580	3%	506	6
04FE03J6	0.0819	1.4%	0.0562	4%	508	7

Sample: EB3 Adaminaby Group Barra, Creek Mudgee (GR 759030 6389930) (ICMPS)

analysis	²⁰⁶ Pb/ ²³⁸ U	Std Er	²⁰⁷ Pb/ ²⁰⁶ Pb	Std Er	²⁰⁶ Pb/ ²³⁸ U age	Std Er
01MR29C11	0.0734	5%	0.0587	4%	456	23
01MR29B13	0.0747	4%	0.0547	4%	465	20
01MR29D08	0.0769	6%	0.0594	6%	477	29
01MR29D10	0.0781	6%	0.0593	5%	485	29
01MR29E08	0.0789	6%	0.0627	6%	490	27
01MR29D12	0.0790	2%	0.0667	2%	490	11
01MR29E11	0.0790	1%	0.0573	1%	490	6
01MR29B09	0.0797	6%	0.0622	4%	494	29
01MR29C06	0.0804	5%	0.0556	5%	498	26
01MR29D05	0.0805	6%	0.0635	6%	499	28
01MR29B10	0.0828	6%	0.0624	3%	513	30
01MR29C16	0.0839	6%	0.0603	10%	520	31
01MR29E14	0.0888	5%	0.0602	4%	548	26
01MR29B12	0.0894	8%	0.0599	5%	552	42
01MR29B07	0.0909	6%	0.0622	6%	561	32
01MR29A11	0.0971	7%	0.0641	6%	597	40
01MR29C05	0.0978	6%	0.0630	5%	601	34
01MR29B08	0.1016	7%	0.0704	6%	624	45
01MR29B06	0.1050	6%	0.0606	4%	643	37
01MR29E06	0.1107	10%	0.0483	44%	677	65
01MR29D11	0.1241	7%	0.0758	9%	754	55
01MR29C09	0.1434	5%	0.2729	2%	864	43
01MR29D14	0.1435	4%	0.0745	8%	864	31
01MR29C08	0.1459	5%	0.0717	4%	878	45
01MR29C07	0.1476	6%	0.0677	4%	887	52
01MR29E07	0.1504	5%	0.0807	9%	903	42
01MR29D06	0.1538	5%	0.0754	4%	922	43
01MR29D09	0.1599	3%	0.0891	5%	956	32
01MR29E05	0.1647	4%	0.0736	4%	983	38
01MR29A12	0.1690	7%	0.0704	4%	1007	67
01MR29B16	0.1711	6%	0.0708	4%	1018	63
01MR29D07	0.1794	3%	0.0862	7%	1064	35
01MR29A10	0.1800	7%	0.0738	3%	1067	71
01MR29A08	0.1862	5%	0.0893	4%	1101	56
01MR29E10	0.2217	5%	0.1691	6%	1291	59
01MR29C13	0.2282	6%	0.1017	2%	1325	74
01MR29D16	0.2870	4%	0.1006	4%	1627	68
01MR29E13	0.3153	3%	0.1120	3%	1767	58
01MR29A09	0.3264	10%	0.1325	3%	1821	185
01MR29B05	0.3368	6%	0.1511	3%	1871	112
01MR29C14	0.3411	5%	0.1702	3%	1892	96
01MR29C15	0.3482	4%	0.1374	2%	1926	76
01MR29A16	0.3817	6%	0.1524	4%	2084	119
01MR29A15	0.4061	7%	0.1478	4%	2197	159
01MR29B15	0.4143	6%	0.1639	3%	2234	142
01MR29E12	0.4310	5%	0.1754	3%	2310	108
01MR29D15	0.4366	2%	0.1828	1%	2336	36
01MR29C12	0.4391	3%	0.2753	3%	2346	73
01MR29B14	0.4450	6%	0.1798	3%	2373	148
01MR29A14	0.4706	4%	0.1725	3%	2486	92
01MR29D13	0.4726	2%	0.2206	2%	2495	49
01MR29B11	0.4993	4%	0.2277	3%	2611	111
01MR29A13	0.5050	7%	0.1803	3%	2635	190
01MR29E09	0.0433	2%	0.0567		273	6
01MR29C10	0.0674	5%	0.0752		420	23