APPENDICES TO THE THESIS ENTITLED

# *The Origin and Evolution of the Tasmanian Dolerites*

by

**Janet M. Hergt**

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# APPENDIX 1.

## SAMPLE LOCALITIES

All samples collected for analysis have been compiled in this appendix. The specimens are arranged in order of their catalogue numbers beginning with the Tasmanian collection. These are followed by the suite of samples from Portal Peak (Antarctica) generously provided by Prof. Gunter Faure and Teresa Mensing, and a group of samples from western Victoria and Kangaroo Island (southern Australia) provided by Prof. Dave Green.

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| SAMPLE NUMBER | LATITUDE | LONGITUDE | ROCK-TYPE | LOCATION |
|---|---|---|---|---|
| 84 101 | 42° 57.9' S | 147° 12.5' E | Chilled Margin | 0 m from top contact of sheet 2.5 km NE of Longley, south of the road. Red Hill. |
| 84 102 | 42° 58.2' S | 147° 12.0' E | Dolerite | Red Hill intrusion, 2 km NE Longley. Exposed in road cutting |
| 84 103 | 43° 03.9' S | 147° 13.3' E | Dolerite | Red Hill intrusion, summit of Red Hill |
| 84 104 | 43° 03.2' S | 147° 13.2' E | Dolerite | From northern slopes of Red Hill, 300 m ASL |
| 84 105 | 43° 13.0' S | 147° 50.7' E | Sediment | Exposed platform near Remarkable Cave, approx. 5 km south of Port Arthur |
| 84 106 | 43° 13.0' S | 147° 50.7' E | Chilled Margin | ". Directly underlying the contact |
| 84 107 | " | " | Chilled Margin | ". Less than 0.5 m from the contact |
| 84 108 | " | " | Chilled Margin | ". Approx. 1 m from the contact |
| 84 109 | 43° 07.0' S | 147° 45.0' E | Chilled Margin | 1.5 m below contact with Triassic sandstone, roadcutting 2.2 km SE of Nubeena |
| 84 110 | " | " | Dolerite | ". 2 m below contact |
| 84 111 | 43° 04.0' S | 147° 50.0' E | Chilled Margin | Approx. 1.5 m below contact, roadcutting 1.45 km E of Koonya |
| 84 112 | 41° 50.3' S | 146° 49.6' E | Dolerite | NE edge of Great Lake, a few hundred metres NE of intake station |
| 84 113 | 41° 50.4' S | 146° 49.5' E | Dolerite | From a small gulley beside the road at the intake station |
| 84 114 | 41° 40.7' S | 145° 57.6' E | Dolerite | Cradle Mountain, base of Little Horn columns along face track |
| 84 115 | 41° 40.7' S | 145° 57.4' E | Chilled Margin | Cradle Mountain, approx. 5 m above the contact |
| 84 116 | 41° 41.0' S | 145° 57.1' E | Dolerite | Summit of Cradle Mountain |
| 84 117 | 41° 41.2' S | 145° 57.2' E | Dolerite | From track leading to Cradle Summit, 1400 m ASL |
| 84 118 | 41° 38.6' S | 146° 42.9' E | Dolerite | Golden Valley, 1.75 km south of Exton junction |
| 84 119 | 41° 32.0' S | 147° 40.0' E | Dolerite | Ben Lomond, Ski Village. Sample from creek bed adjacent to amenities block |
| 84 120 | 41° 31.0' S | 147° 39.5' E | Dolerite | Ben Lomond, top of Jacobs Ladder. Roadside exposure |
| 84 121 | " | " | Dolerite | Ben Lomond, Hanging Corner on Jacobs Ladder |
| 84 122 | " | " | Dolerite | Ben Lomond, base of Jacobs Ladder |
| 84 123 | 43° 04.3' S | 147° 13.8' E | Dolerite | Red Hill intrusion, outcrop in Snug River approx. 100 m from eastern contact |
| 84 124 | 43° 04.4' S | 147° 14.2' E | Dolerite | Red Hill intrusion, Snug River, beneath the small bridge west of 84 123 |
| 84 125 | 43° 04.4' S | 147° 14.1' E | Dolerite | Red Hill intrusion, Snug River, 100 m or so SE of the bridge |
| 84 126 | 43° 04.4' S | 147° 14.0' E | Dolerite | Red Hill intrusion, Snug River, continuing upstream |
| 84 127 | 43° 04.5' S | 147° 13.9' E | Dolerite | Red Hill intrusion, Snug River, approx the centre of the dyke |
| 84 128 | 43° 04.7' S | 147° 13.3' E | Chilled Margin | Red Hill intrusion, Snug River, 0.5 m below the western contact |
| 84 129 | " | " | Chilled Margin | ". Only 30 cm from the contact |
| 84 130 | " | " | Dolerite | ". Approx. 15 m from the western contact |
| 84 131 | 43° 04.6' S | 147° 13.9' E | Dolerite | O'briens Hill. immediately south of Snug River |
| 84 132 | 43° 04.6' S | 147° 13.8' E | Dolerite | O'briens Hill, approx the centre of the dyke on the road south of the river |
| 84 133 | 43° 04.6' S | 147° 13.9' E | Dolerite | Northern flank of O'briens Hill, south of the road above the river 190 m ASL |
| 84 134 | 43° 04.7' S | 147° 13.9' E | Dolerite | Keeping in about the centre of the dyke on O'briens Hill, 215 m ASL |
| 84 135 | 43° 05.0' S | 147° 13.9' E | Dolerite | Near the top of O'briens Hill beside a large clearing, 315 m ASL |
| 84 136 | 43° 03.6' S | 147° 13.1' E | Dolerite | Red Hill, northern part of dyke along Van Morey Rd. 240 m ASL |
| 84 137 | 43° 03.6' S | 147° 12.9' E | Dolerite | ", Approx. 350 m east of the western margin. 260 m ASL |
| 84 138 | 43° 02.3' S | 147° 13.7' E | Chilled Margin | Red Hill intrusion, Small roadside exposure along Nierra Rd. 165 m ASL |
| 84 139 | 43° 04.7' S | 147° 13.1' E | Sediment | Red Hill, Snug River, a few metres west of the western contact |
| 84 140 | 43° 17.0' S | 147° 12.0' E | Chilled Margin | Nine Pin Point, dolerite transgressive to Permian sediments in roadcutting |
| 84 141 | 43° 14.2' S | 147° 08.2' E | Chilled Margin | Cygnet, approx. 1 m above a low angle contact with Triassic sandstone, roadcutting |
| 84 142 | 43° 14.1' S | 147° 08.1' E | Sediment | Cygnet, close to the chilled contact |
| 84 143 | 43° 19.0' S | 147° 03.0' E | Chilled Margin | Esperance Point close to contact |
| 84 144 | 43° 01.8' S | 147° 20.0' E | Chilled Margin | Blackmans Bay, 0 m from contact, 4 km S of town outskirts, near the home "Clarach". |
| 84 145 | " | " | Dolerite | " 5 m below contact. |
| 84 146 | " | " | Sediment | " 1 m above contact |
| 84 147 | " | " | Chilled Margin | " 0 m from contact about 20 m south of 84 144 |
| 84 148 | " | " | Chilled Margin | ". Basal contact of thin sheet above the main intrusion |
| 84 149 | 42° 55.0' S | 147° 20.0' E | Chilled Margin | Southern Expressway, 0 m from contact, adjacent to the Mt. Nelson turn-off |
| 84 150 | " | " | Chilled Margin | " |
| 84 151 | " | " | Sediment | ". 1-1.5 m above the contact with the dolerite |
| 84 152 | 42° 53.9' S | 147° 14.6' E | Chilled Margin | Contact at the base of the Mt. Wellington sheet, 905 m ASL |
| 84 153 | 42° 53.8' S | 147° 14.6' E | Dolerite | Mt. Wellington, 920 m ASL |
| 84 154 | 42° 53.5' S | 147° 14.5' E | Dolerite | Mt. Wellington, 940 m ASL |
| 84 155 | 42° 53.5' S | 147° 14.4' E | Dolerite | Mt. Wellington, 958 m ASL |
| 84 156 | 42° 53.5' S | 147° 14.3' E | Dolerite | Mt. Wellington, 965 m ASL |
| 84 157 | 42° 53.5' S | 147° 14.2' E | Dolerite | Mt. Wellington, 985 m ASL |
| 84 158 | 42° 53.5' S | 147° 14.1' E | Dolerite | Mt. Wellington, 1000 m ASL, sample from "The Chalet" |
| 84 159 | 42° 53.4' S | 147° 14.0' E | Dolerite | Mt. Wellington, 1015 m ASL, first in situ dolerite above 84 158 |
| 84 160 | 42° 53.4' S | 147° 13.8' E | Dolerite | Mt. Wellington, 1030 m ASL |

| SAMPLE NUMBER | LATITUDE | LONGITUDE | ROCK-TYPE | LOCATION |
|---|---|---|---|---|
| 84 161 | 42° 53.4' S | 147° 13.5' E | Dolerite | Mt. Wellington, 1060 m ASL, last in situ outcrop before the hairpin bend to the summit |
| 84 162 | 42° 53.5' S | 147° 13.3' E | Dolerite | Mt. Wellington, 1165 m ASL, blasted roadside outcrop |
| 84 163 | 42° 53.6' S | 147° 13.5' E | Dolerite | Mt. Wellington, 1185 m ASL |
| 84 164 | 42° 53.6' S | 147° 13.8' E | Dolerite | Mt. Wellington, 1210-1215 m ASL |
| 84 165 | 42° 53.8' S | 147° 14.2' E | Dolerite | Mt. Wellington, 1260-1265 m ASL |
| 84 166 | 42° 53.9' S | 147° 14.2' E | Dolerite | Mt. Wellington, at most 1 m below 1270 m trig. marker at summit |
| 84 167 | 42° 55.3' S | 147° 18.4' E | Chilled Margin | Southern Expressway, south of 84 149, block of Permian marl in the dolerite. |
| 84 168 | 41° 50' S | 146° 49.5' E | Chilled Margin | Great Lake borehole 5086 (Hydro-Electric Commission) 5" at 1048' 3" |
| 84 169 | " | " | Chilled Margin | Great Lake borehole 5086 (Hydro-Electric Commission) 6" at 1046' 9.5" |
| 84 170 | " | " | Chilled Margin | Great Lake borehole 5086 (Hydro-Electric Commission) 6.5" at 1044' 8" |
| 84 171 | " | " | Dolerite | Great Lake borehole 5086 (Hydro-Electric Commission) 2.5" at 1038' 8" |
| 84 172 | " | " | Dolerite | Great Lake borehole 5086 (Hydro-Electric Commission) 4" at 1029' 6" |
| 84 173 | " | " | Dolerite | Great Lake borehole 5086 (Hydro-Electric Commission) 4" at 990' |
| 84 174 | " | " | Dolerite | Great Lake borehole 5086 (Hydro-Electric Commission) 4.5" at 951' |
| 84 175 | " | " | Dolerite | Great Lake borehole 5086 (Hydro-Electric Commission) 4.5" at 907' |
| 84 176 | " | " | Dolerite | Great Lake borehole 5086 (Hydro-Electric Commission) 5" at 875' |
| 84 177 | " | " | Dolerite | Great Lake borehole 5086 (Hydro-Electric Commission) 2" at 792' |
| 84 178 | " | " | Dolerite | Great Lake borehole 5086 (Hydro-Electric Commission) 2" at 745' |
| 84 179 | " | " | Dolerite | Great Lake borehole 5086 (Hydro-Electric Commission) 5.5" at 698' |
| 84 180 | " | " | Dolerite | Great Lake borehole 5086 (Hydro-Electric Commission) 3" at 643' 6" |
| 84 181 | " | " | Dolerite | Great Lake borehole 5086 (Hydro-Electric Commission) 4" at 592' |
| 84 182 | " | " | Dolerite | Great Lake borehole 5086 (Hydro-Electric Commission) 4" at 542' |
| 84 183 | " | " | Dolerite | Great Lake borehole 5086 (Hydro-Electric Commission) 3" at 495' |
| 84 184 | " | " | Dolerite | Great Lake borehole 5086 (Hydro-Electric Commission) 4" at 448' 6" |
| 84 185 | " | " | Dolerite | Great Lake borehole 5086 (Hydro-Electric Commission) 3" at 399' |
| 84 186 | " | " | Dolerite | Great Lake borehole 5086 (Hydro-Electric Commission) 5.5" at 355' 6" |
| 84 187 | " | " | Dolerite | Great Lake borehole 5086 (Hydro-Electric Commission) 4.5" at 338' |
| 84 188 | " | " | Dolerite | Great Lake borehole 5086 (Hydro-Electric Commission) 6" at 278' |
| 84 189 | " | " | Dolerite | Great Lake borehole 5086 (Hydro-Electric Commission) 4" at 211' |
| 84 190 | " | " | Dolerite | Great Lake borehole 5086 (Hydro-Electric Commission) 3" at 165' |
| 84 191 | " | " | Dolerite | Great Lake borehole 5086 (Hydro-Electric Commission) 4" at 95' |
| 84 192 | " | " | Dolerite | Great Lake borehole 5086 (Hydro-Electric Commission) 5" at 48' |
| 84 193 | 42° 34.0' S | 147° 49.5' E | Sediment | 5 km west of Orford, Large quarry near Black Bridge Creek |
| 84 194 | 42° 01.5' S | 147° 30.0' E | Dolerite | 1.5 km north of Ross township in railway cutting, 15m or so from contact |
| 84 195 | 42° 12.0' S | 147° 23.5' E | Chilled Margin | 1.5 km north of Antill Ponds along Midland Hwy. 0 m from bottom contact |
| 84 196 | 42° 24.3' S | 147° 15.6' E | Chilled Margin | North of Bishton Creek on the Midland Hwy (north of Spring Hill) 1 m from contact |
| 84 197 | 42° 26.5' S | 147° 08.5' E | Dolerite | Apsley, small columns of different orientation described by S Forsyth Dept. Mines |
| 84 198 | 42° 17.4' S | 147° 03.6' E | Dolerite | Bryans Creek 2.5 km W of Woods Quoin. "Rosette rock" described by S Forsyth. |
| 84 199 | 42° 11.5' S | 147° 07.0' E | Chilled Margin | 3 km W of Lake Crescent, hornfels "skins" nearby indicate 0 m from contact |
| 84 200 | 42° 08.0' S | 147° 13.0' E | Chilled Margin | 3 km NE of Interlaken; pavements with hornfels skins close-by. 1 m from contact |
| 84 201 | 42° 09.0' S | 147° 10.0' E | Dolerite | Interlaken Canal, no contact exposed; ? m from contact |
| 84 202 | | | Dolerite | Woods Lake, fine-grained dykelets intrude coarser dolerite. Too altered, not analysed. |
| 84 203 | 42° 26.4' S | 147° 14.3' E | Chilled Margin | 0 m from contact; small quarry 5.5km S of Spring Hill on Nth side of old Midland Hwy. |
| 84 204 | 42° 24.6' S | 147° 15.7' E | Dolerite | Spring Hill, upper level of rd. cutting. Fine dolerite appears to intrude coarser rock |
| 84 205 | 41° 14.5' S | 146° 33.7' E | Chilled Margin | 0 m from contact with Triassic sandstone, E of Harford just west of Rubicon bridge |
| 84 206 | 43° 01.6' S | 147° 15.5' E | Chilled Margin | Margate Borehole 1. Core samples courtesy Dept. Mines Tas. 306.17 m |
| 84 207 | " | " | Dolerite | Margate Borehole 1. Core samples courtesy Dept. Mines Tas. 308.15 m |
| 84 208 | " | " | Dolerite | Margate Borehole 1. Core samples courtesy Dept. Mines Tas. 310.45 m |
| 84 209 | " | " | Dolerite | Margate Borehole 1. Core samples courtesy Dept. Mines Tas. 311.20 m |
| 84 210 | " | " | Dolerite | Margate Borehole 1. Core samples courtesy Dept. Mines Tas. 314.20 m |
| 84 211 | " | " | Dolerite | Margate Borehole 1. Core samples courtesy Dept. Mines Tas. 320.20 m |
| 84 212 | " | " | Dolerite | Margate Borehole 1. Core samples courtesy Dept. Mines Tas. 331.20 m |
| 84 213 | 42° 46' S | 147° 13' E | Chilled Margin | Granton Borehole 1. Core samples courtesy Dept. Mines Tas. 544.07 m |
| 84 214 | " | " | Chilled Margin | Granton Borehole 1. Core samples courtesy Dept. Mines Tas. 544.88 m |
| 84 215 | " | " | Dolerite | Granton Borehole 1. Core samples courtesy Dept. Mines Tas. 546.00 m |
| 84 216 | " | " | Dolerite | Granton Borehole 1. Core samples courtesy Dept. Mines Tas. 553.00 m |
| 84 217 | " | " | Dolerite | Granton Borehole 1. Core samples courtesy Dept. Mines Tas. 555.79 m |
| 84 218 | " | " | Dolerite | Granton Borehole 1. Core samples courtesy Dept. Mines Tas. 558.84 m |
| 84 219 | " | " | Dolerite | Granton Borehole 1. Core samples courtesy Dept. Mines Tas. 560.00 m |
| 84 220 | " | " | Dolerite | Granton Borehole 1. Core samples courtesy Dept. Mines Tas. 561.00 m |

| SAMPLE NUMBER | LATITUDE | LONGITUDE | ROCK-TYPE | LOCATION |
|---|---|---|---|---|
| 84 221 | 42° 40' S | 147° 07' E | Chilled Margin | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 216.38 m |
| 84 222 | " | " | Chilled Margin | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 219.23 m |
| 84 223 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 227.38 m |
| 84 224 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 235.24 m |
| 84 225 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 243.47 m |
| 84 226 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 250.38 m |
| 84 227 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 265.61 m |
| 84 228 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 283.08 m |
| 84 229 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 298.65 m |
| 84 230 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 315.41 m |
| 84 231 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 331.49 m |
| 84 232 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 347.45 m |
| 84 233 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 361.04 m |
| 84 234 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 379.45 m |
| 84 235 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 392.46 m |
| 84 236 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 409.53 m |
| 84 237 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 426.76 m |
| 84 238 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 434.10 m |
| 84 239 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 445.99 m |
| 84 240 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 456.18 m |
| 84 241 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 464.46 m |
| 84 242 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 475.12 m |
| 84 243 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 486.33 m |
| 84 244 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 497.55 m |
| 84 245 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 504.32 m |
| 84 246 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 516.14 m |
| 84 247 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 528.09 m |
| 84 248 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 538.05 m |
| 84 249 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 549.27 m |
| 84 250 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 559.30 m |
| 84 251 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 569.94 m |
| 84 252 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 579.13 m |
| 84 253 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 588.78 m |
| 84 254 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 598.95 m |
| 84 255 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 609.25 m |
| 84 256 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 621.10 m |
| 84 257 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 630.05 m |
| 84 258 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 641.32 m |
| 84 259 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 651.10 m |
| 84 260 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 662.11 m |
| 84 261 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 668.76 m |
| 84 262 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 681.81 m |
| 84 263 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 693.12 m |
| 84 264 | 41° 39' S | 148° 06' E | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 67.69 m |
| 84 265 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 82.75 m |
| 84 266 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 97.76 m |
| 84 267 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 112.75 m |
| 84 268 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 121.75 m |
| 84 269 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 133.78 m |
| 84 270 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 142.79 m |
| 84 271 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 151.75 m |
| 84 272 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 163.81 m |
| 84 273 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 178.81 m |
| 84 274 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 187.82 m |
| 84 275 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 199.83 m |
| 84 276 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 208.81 m |
| 84 277 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 220.81 m |
| 84 278 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 229.82 m |
| 84 279 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 241.78 m |
| 84 280 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 253.84 m |

| SAMPLE NUMBER | LATITUDE | LONGITUDE | ROCK-TYPE | LOCATION |
|---|---|---|---|---|
| 84 281 | 41° 39' S | 148° 06' E | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 262.84 m |
| 84 282 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 274.86 m |
| 84 283 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 283.86 m |
| 84 284 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 295.87 m |
| 84 285 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 301.87 m |
| 84 286 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 313.90 m |
| 84 287 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 322.92 m |
| 84 288 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 334.93 m |
| 84 289 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 346.92 m |
| 84 290 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 355.94 m |
| 84 291 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 367.96 m |
| 84 292 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 379.97 m |
| 84 293 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 388.97 m |
| 84 294 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 397.99 m |
| 84 295 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 406.99 m |
| 84 296 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 416.00 m |
| 84 297 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 425.01 m |
| 84 298 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 443.00 m |
| 84 299 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 449.00 m |
| 84 300 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 451.95 m |
| 84 301 | " | " | Chilled Margin | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 452.60 m |
| 84 302 | 42° 51' S | 147° 15' E | Dolerite | Glenorchy Borehole. Core samples courtesy Dept. Mines Tas. 199.95 m |
| 84 303 | " | " | Dolerite | Glenorchy Borehole. Core samples courtesy Dept. Mines Tas. 201.96 m |
| 84 304 | " | " | Dolerite | Glenorchy Borehole. Core samples courtesy Dept. Mines Tas. 203.50 m |
| 84 305 | " | " | Dolerite | Glenorchy Borehole. Core samples courtesy Dept. Mines Tas. 205.94 m |
| 84 306 | " | " | Dolerite | Glenorchy Borehole. Core samples courtesy Dept. Mines Tas. 210.44 m |
| 84 307 | " | " | Dolerite | Glenorchy Borehole. Core samples courtesy Dept. Mines Tas. 217.40 m |
| 84 308 | " | " | Dolerite | Glenorchy Borehole. Core samples courtesy Dept. Mines Tas. 234.52 m |
| 84 309 | " | " | Dolerite | Glenorchy Borehole. Core samples courtesy Dept. Mines Tas. 257.33 m |
| 84 310 | " | " | Dolerite | Glenorchy Borehole. Core samples courtesy Dept. Mines Tas. 286.36 m |
| 84 311 | " | " | Dolerite | Glenorchy Borehole. Core samples courtesy Dept. Mines Tas. 304.34 m |
| 84 312 | " | " | Dolerite | Glenorchy Borehole. Core samples courtesy Dept. Mines Tas. 324.84 m |
| 84 313 | " | " | Dolerite | Glenorchy Borehole. Core samples courtesy Dept. Mines Tas. 345.80 m |
| 84 314 | " | " | Dolerite | Glenorchy Borehole. Core samples courtesy Dept. Mines Tas. 366.06 m |
| 84 315 | " | " | Dolerite | Glenorchy Borehole. Core samples courtesy Dept. Mines Tas. 387.71 m |
| 84 316 | " | " | Dolerite | Glenorchy Borehole. Core samples courtesy Dept. Mines Tas. 405.69 m |
| 84 317 | " | " | Dolerite | Glenorchy Borehole. Core samples courtesy Dept. Mines Tas. 424.89 m |
| 84 318 | " | " | Dolerite | Glenorchy Borehole. Core samples courtesy Dept. Mines Tas. 447.75 m |
| 84 319 | " | " | Dolerite | Glenorchy Borehole. Core samples courtesy Dept. Mines Tas. 460.55 m |
| 84 320 | " | " | Dolerite | Glenorchy Borehole. Core samples courtesy Dept. Mines Tas. 480.67 m |
| 84 321 | " | " | Dolerite | Glenorchy Borehole. Core samples courtesy Dept. Mines Tas. 482.50 m |
| 84 322 | " | " | Dolerite | Glenorchy Borehole. Core samples courtesy Dept. Mines Tas. 489.20 m |
| 84 323 | " | " | Chilled Margin | Glenorchy Borehole. Core samples courtesy Dept. Mines Tas. 490.42 m |
| 84 324 | " | " | Chilled Margin | Glenorchy Borehole. Core samples courtesy Dept. Mines Tas. 491.95 m |
| 87 85 | 83° 50' S | 165° 40' E | Sediment | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 18.0 m |
| 87 86 | " | " | Sediment | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 18.5 m |
| 87 87 | " | " | Dolerite | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 19.0 m |
| 87 88 | " | " | Dolerite | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 19.5 m |
| 87 89 | " | " | Dolerite | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 21.0 m |
| 87 90 | " | " | Dolerite | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 24.0 m |
| 87 91 | " | " | Dolerite | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 27.0 m |
| 87 92 | " | " | Dolerite | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 30.0 m |
| 87 93 | " | " | Dolerite | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 33.0 m |
| 87 94 | " | " | Dolerite | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 36.0 m |
| 87 95 | " | " | Dolerite | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 39.0 m |
| 87 96 | " | " | Dolerite | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 42.0 m |
| 87 97 | " | " | Dolerite | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 45.0 m |
| 87 98 | " | " | Dolerite | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 48.0 m |
| 87 99 | " | " | Dolerite | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 51.0 m |
| 87 100 | " | " | Dolerite | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 54.0 m |

| SAMPLE NUMBER | LATITUDE | LONGITUDE | ROCK-TYPE | LOCATION |
|---|---|---|---|---|
| 87 101 | 83° 50'S | 165° 40' E | Dolerite | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 57.0 m |
| 87 102 | " | " | Dolerite | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 60.0 m |
| 87 103 | " | " | Dolerite | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 63.0 m |
| 87 104 | " | " | Dolerite | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 66.0 m |
| 87 105 | " | " | Dolerite | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 69.0 m |
| 87 106 | " | " | Dolerite | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 72.0 m |
| 87 107 | " | " | Dolerite | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 75.0 m |
| 87 108 | " | " | Dolerite | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 78.0 m |
| 87 109 | " | " | Dolerite | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 81.0 m |
| 87 110 | " | " | Dolerite | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 84.0 m |
| 87 111 | " | " | Dolerite | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 87.0 m |
| 87 112 | " | " | Dolerite | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 90.0 m |
| 87 113 | " | " | Dolerite | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 93.0 m |
| 87 114 | " | " | Dolerite | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 96.0 m |
| 87 115 | " | " | Dolerite | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 99.0 m |
| 87 116 | " | " | Dolerite | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 102.0 m |
| 87 117 | " | " | Dolerite | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 105.0 m |
| 87 118 | " | " | Dolerite | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 111.0 m |
| 87 119 | " | " | Dolerite | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 117.0 m |
| 87 120 | " | " | Dolerite | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 123.0 m |
| 87 121 | " | " | Dolerite | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 129.0 m |
| 87 122 | " | " | Dolerite | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 135.0 m |
| 87 123 | " | " | Dolerite | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 141.0 m |
| 87 124 | " | " | Dolerite | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 145.5 m |
| 87 125 | " | " | Dolerite | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 147.0 m |
| 87 126 | " | " | Dolerite | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 148.0 m |
| 87 127 | " | " | Sediment | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 149.5 m |
| 87 128 | " | " | Sediment | Portal Peak Antarctica. Samples courtesy Gunter Faure and Teresa Mensing. 152.0 m |
| 87 129 | 37° 35.9' S | 141° 43.9' E | Alkali Basalt | Koroite Hill, 3 km E of Coleraine Western Victoria. Sample courtesy Tas. Uni. |
| 87 130 | " | " | Tholeiitic Basalt | Koroite Hill, 3 km E of Coleraine Western Victoria. Sample courtesy Tas. Uni. |
| 87 131 | " | " | Tholeiitic Basalt | Koroite Hill, 3 km E of Coleraine Western Victoria. Sample courtesy Tas. Uni. |
| 87 132 | 37° 12.9'S | 141° 30.0'E | Alkali Basalt | Harrow, approx. 50 km N Coleraine Western Victoria. Sample courtesy Tas. Uni. |
| 87 133 | 35° 38.3' S | 137° 28.9' E | Tholeiitic Basalt | 2.5 km SE Wisanger Kangaroo Is. South Australia. Sample courtesy Tas. Uni. |
| 87 134 | 35° 44.3' S | 138° 00.5' E | Tholeiitic Plug | 8 km E Penneshaw, Kangaroo Is. South Australia. Sample courtesy Tas. Uni. |
| 87 135 | 35° 39.0' S | 137° 37.3' E | Tholeiitic Basalt | Quarry sample 1 km W Kingscote Kangaroo Is. S Australia. Sample courtesy Tas. Uni. |

# APPENDIX 2.

## SAMPLE PREPARATION AND ANALYTICAL TECHNIQUES

Various techniques have been employed in the analysis of close to 300 rock samples. The sample preparation and analytical methods are outlined in this appendix and are divided into the following sections:

1. Crushing
2. Determination of $H_2O$+, $H_2O$-, $CO_2$ and FeO
3. Preparation of glass discs and pressed powder pellets and their analysis by XRF spectrometry
4. Determination of trace element concentrations by INAA
5. Determination of trace element concentrations by SSMS
6. Determination of Sr and Nd isotopic compositions
7. Determination of Pb isotopic compositions
8. Determination of O isotopic compositions

### 2.1 CRUSHING

The samples collected from outcrops were reduced to gravel sized chips using an hydraulic splitter. Care was taken in removing surfaces bearing metal from hammer blows, rare carbonate veins, and (in the case of many of the chilled margins) rust colored alteration along joint planes.

Specimens obtained from drill core were first ground on a diamond lap to remove any surface contamination produced during drilling, and the saw marks developed during halving of the core (in the case of samples obtained from the Tasmanian Department of Mines). It was also necessary to clean the Antarctic samples in this manner as they consisted of small sawn blocks; in this case splitting to a smaller size was not necessary.

Where there were no constraints on the sample size, approximately 1 kg of the chips were crushed and an aliquot further ground to powder in a tungsten carbide swing mill. In addition to the Antarctic specimens (a maximum of ~10-20 g for most samples), many of the core samples were small enough to be crushed and ground into powder in one step. Between samples the swing mills were cleaned by crushing washed quartz pebbles and rinsing the mills in alcohol.

Powders prepared in this manner were used in all whole-rock analyses with only two exceptions. Because crushing in tungsten carbide contributes Co and Ta to the sample (as well as W), the Co analyses performed on chilled margin samples were obtained by taking a separate aliquot of chips and crushing them in steel mills. The Pb whole-rock isotopic compositions were also obtained from chips saved from the original hand-specimen.

### 2.2 DETERMINATION OF $H_2O$+, $H_2O$-, $CO_2$ AND FeO

The method of determining the amount of $H_2O$- (the hygroscopic water absorbed onto grain surfaces), $H_2O$+ (the water held in silicate structures) and $CO_2$ (also held in the matrix) was by gravimetric analysis. In the procedure used, approximately 0.5 g of rock powder was accurately weighed into a platinum boat (also of accurately known weight) and then placed into an oven set at ~100-110°C for several hours (or overnight). This removed the hygroscopic water and the loss of weight ($H_2O$-) was recorded.

The remaining water and $CO_2$ were liberated at higher temperatures and were determined after removal of $H_2O$-. The platinum boat was placed in a combustion tube within a furnace (set at ~1000°C) for 30 minutes. A stream of nitrogen was passed through the tube to flush the volatiles liberated from the sample. Two absorption tubes were assembled at the end of the combustion tube; the first containing powdered $P_2O_5$ mixed with quartz granules to absorb water; the second containing sodium hydroxide on support granules which absorbs $CO_2$. The tubes were weighed between samples and a blank was measured at the beginning and end of each day. The increase in weight of each tube was recalculated to give the weight percent of $H_2O$ and $CO_2$ in each sample. These analyses were performed only once for each sample.

The total Fe content determined by XRF analysis as $Fe_2O_3$ (see later discussion) was resolved into FeO and $Fe_2O_3$ by a method involving dissolution and titration. In this method approximately 0.5 g of rock powder was weighed into a platinum crucible (containing a small platinum wire to prevent "bumping" during heating) and was dampened with recently boiled distilled water. A mixture of HF(conc) and $H_2SO_4$(1:1) was poured into the crucible (~10 ml) and then covered by a platinum lid. The crucible was carefully heated over a bunsen flame until fuming began, at which point the heat was reduced and the mixture was left to react for 3 minutes. The contents of the crucible was carefully rinsed into a beaker containing a solution of boric acid, sulphuric acid, phosphoric acid and a few drops of 0.5% barium diphenylamine sulphonate indicator. This was quickly titrated against a standard solution of $K_2Cr_2O_7$ to determine FeO. $Fe_2O_3$ was then calculated by difference.

All results were duplicated to eliminate possible errors resulting from incomplete dissolution or oxidation of the solution prior to titration. To check the results further, several samples were re-analysed using a similar but more sophisticated technique developed by Kiss (1977), and the results agreed to within expected error (i.e. ~2-3%).

## 2.3 PREPARATION OF GLASS DISCS AND PRESSED POWDER PELLETS AND THEIR ANALYSIS BY XRF SPECTROMETRY.

Most of the geochemical data were determined using XRF spectrometry. The major elements were obtained by analysis of fused glass discs and the trace elements were determined from analysis of pressed powder pellets.

The trace element pellets were made by combining ~2.5 g of sample powder with a few drops of PVA solution (to help bind the powder) and gently pressed using a hand-held assembly to produce a circular disc. Boric acid powder was packed around and on top of each disc which was then pressed at higher pressure into a rigid pellet. After drying for a few minutes under a heat lamp the samples were ready for analysis.

For the major element analysis fused glass discs were used. Although the methods used are similar to those of Norrish and Hutton (1969), some important differences have been made and elaboration is useful. The glass produced for analysis contains close to 0.28 g of the sample powder and 1.5 g of the lithium borate flux. Instead of painstakingly weighing exact amounts of these powders, the balance was linked to a computer and disc-drive. The weights were recorded onto discs for later data reduction, saving considerable time and effort in sample preparation. In some labs an oxidizing agent such as $NaNO_3$ or $LiNO_3$ is also added at this stage. Instead, the sample-flux mixtures were sintered at 180°C for 15 minutes prior to fusing, and duplicated results using the two methods show good agreement.

After 15 minutes sintering, the samples were transferred to a second furnace (800°C) for 15 minutes. At this temperature the mixture melts but does not necessarily homogenise. For most of the samples, the glasses were remelted and homogenised by being held and agitated in a flame for ~10 minutes prior to pouring the melt droplet onto a graphite disc and pressing it flat with an aluminium plunger. The Portal Peak, western Victorian and Kangaroo Island samples were analysed later than most other samples. Instead of holding the samples in a flame to homogenise them, a rocking-furnace was used and the crucibles were taken from this furnace, and the glass poured and pressed into discs.

The theory on which XRF analysis is based is detailed in a number of excellent textbooks and publications and is not dealt with here. The largest error involved in this technique arises from absorption of the fluorescent x-rays by the sample. Clearly, if not all of the x-rays released by atoms of the element measured manage to pass out of the sample, then the concentration calculated will be low compared to the true value. Although the error introduced by absorption decreases with decreasing abundance of the element, proper correction for absorption requires the determination of mass absorption coefficients.

In this study, direct measurements were made (in duplicate) of the Rb and Sr absorption coefficients for each sample analysed. These absorption coefficients were applied to elements with fluorescent wavelengths between 0.7 and 1.0Å. Other trace elements were corrected by calculating mass absorption coefficients, from major element analyses and published absorption coefficients.

Other errors involved in the determination of concentrations by XRF include corrections for high or non-linear backgrounds (produced by scatter) and interferences by spectra from other elements. These have been corrected using the methods of Norrish and Chappell (1967) by a program developed by Dr. B.W. Chappell.

Calibration of the two XRF spectrometers used in the major and trace element analyses (Siemens SRS300, and Philips PW1400 respectively) was originally performed using synthetic standards prepared using chemicals of high purity, and well documented international standards. These are periodically re-analysed in addition to a number of "in-house" standards calibrated for more routine use.

## 2.4 DETERMINATION OF TRACE ELEMENT CONCENTRATIONS BY INAA

Samples chosen for instrumental neutron activation analysis (INAA) were packed into small polythene capsules which were sealed by heating. The weight of sample used was generally ~0.3 g. No special treatment of the sample powder was required; however, plastic gloves were worn at all times to ensure that the vials remained free from surface contamination.

Each batch included fourteen unknowns and a standard (in this case the in-house basalt standard). These were irradiated in a flux of ~4x$10^{12}$ n/cm$^2$/s for 24 hours and the known Fe contents of the samples (from XRF) were used as flux monitors.

After a week of "cooling" the gamma-ray spectra were acquired using a germanium low-energy photon spectrometer for Ce, Nd, Sm, Eu, Gd, Tb, Yb, Lu, Ta, and a lithium-drifted germanium detector for La, Yb, Lu, Ta, Eu, Hf, and Cs (Table 2.1; from Chappell and Hergt, in prep.).

The counts were reduced to concentrations using a computer program developed by Dr. B.W. Chappell, and multiple photopeak data acquired for a single element were weighted inversely as the variance of the errors.

Table 2.1 Instrumental conditions for INAA analysis and coefficient of variation (σ%) of the counting error of the various determinations

| Count | | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| Approx. days after irradiation | | 3.5-5 | 8-11 | 15-30 | 30-60 | 450 | 450 |
| Detector* | | Planar | Coaxial | Planar | Coaxial | Planar | Coaxial |
| Approx. length of count (sec.) | | 7500 | 16000 | 20000 | 20000 | 20000 | 20000 |
| Elements | keV | | | | | | |
| Na | 1369 | | 0.6 | | | | |
| Fe | 1099 | | | | 0.17 | | |
| Fe | 1292 | | | | 0.19 | | |
| Sc | 889 | | | | 0.06 | | 0.15 |
| Sc | 1121 | | | | 0.06 | | 0.17 |
| Cr | 320 | | | | 0.8 | | |
| Co | 1173 | | | | 0.21 | | 0.09 |
| Co | 1333 | | | | 0.22 | | 0.09 |
| Cs | 605 | | | | 21 | | 1.7 |
| Cs | 796 | | | | 9.1 | | 2.1 |
| Ba | 124 | | | 3.9 | | | |
| Ba | 216 | | 13 | | | | |
| Ba | 496 | | 12 | | | | |
| La | 329 | | 2.6 | | | | |
| La | 487 | | 1.5 | | | | |
| La | 816 | | 3.6 | | | | |
| La | 1597 | | 0.6 | | | | |
| Ce | 145 | | | 1.1 | | | |
| Nd | 91 | | | 2.4 | | | |
| Sm | 103 | 0.4 | | 0.5 | | | |
| Eu | 122 | | | 1.2 | | (0.19) | |
| Eu | 779 | | | | 9.5 | | 1.3 |
| Eu | 1086 | | | | | | 1.7 |
| Eu | 1408 | | | | 2.1 | | 0.7 |
| Gd | 97 | | | | | 4.3 | |
| Gd | 103 | | | | | 5.2 | |
| Tb | 87 | | | 3.2 | | | |
| Tb | 299 | | | | 11 | | |
| Ho | 81 | 6.0 | | | | | |
| Yb | 114 | 5.3 | | | | | |
| Yb | 177 | | | 5.3 | | | |
| Yb | 396 | | 2.2 | | | | |
| Lu | 113 | 8.3 | | | | | |
| Lu | 208 | 13 | 1.7 | 2.4 | | | |
| Hf | 133 | | | 2.1 | | | |
| Hf | 482 | | | | 3.5 | | |
| Ta | 100 | | | 41 | | 12 | |
| Ta | 152 | | | 68 | | | |
| Ta | 1221 | | | | 13 | | |
| Th | 312 | | | | 3.2 | | |
| U | 106 | 21 | | | | | |

Footnotes to table 2.1

* Coaxial detector was an ORTEC GEM10175 with 17.5% efficiency and resolution of 1.85 keV at 1333 keV. For counts 1 and 3 a 6 cm diameter and for count 5 a 36 mm diameter ORTEC detectors were used, with resolutions of 500 and 700 eV, respectively, at 122 keV. With the 16 mm planar detector that we now have available, better precisions can be obtained on count 3 without loss of resolution.

Data are from the first of six replicate analyses of the Mt Wellington chilled margin sample 84-152. Errors vary slightly from count to count depending on the precise time of counting and the length of that count.

Data show which photopeaks are used for the analysis of each element and when. Numbers are the per cent. counting error in net intensity peak minus background and are a component of the total final error .

An estimate of the absolute counting errors can be obtained by combining these data with the mean values.

The very precise Eu value of 0.19% at122 keV on count 5 was not used since at the time the resolution of the large planar detector was poor and slightly variable, and other good data for Eu are available.

These data should not be taken as a guide to counting errors in samples of different compositions. e.g. the high Sc in the chilled margins means that count 4 is much less efficient for all other elements measured at that time.

## 2.5 DETERMINATION OF TRACE ELEMENT CONCENTRATIONS BY SSMS

The trace element compositions of seven samples from western Victoria and Kangaroo Island (supplied by Prof. D.H. Green) were analysed using spark-source mass spectrometry. In this method, each sample is well-mixed with a Lu carbide standard in a ratio of 1:1 (using 100 mg of each powder) in a carefully cleaned agate mill. Electrodes are prepared from this mix by pressing the powder into a ~1 mm diametre hole bored through a polypropylene slug.

After initial sparking (to remove any possible surface contamination), a photoplate is placed in position and a series of 15-16 graded exposures recorded. The species recorded on the photographic plate are separated in the spectrometer according to their mass:charge ratio and include elemental ions, carbides, and polyatomic ions; care is used when reading the plates and reducing the data to eliminate any interferences. The intensities of the lines recorded on the plates (relative to the Lu internal standard) are obtained using a densitometer and are related to concentration by reference to a calibration curve developed by Dr. S.R. Taylor using BCR-1.

## 2.6 DETERMINATION OF Sr AND Nd ISOTOPIC COMPOSITIONS

Most of the Sr and Nd isotopic data were obtained from spiked samples despite the fact that elemental concentrations of Sr, Rb, Nd and Sm were obtained by other techniques (i.e. XRF and INAA). Aliquots from the same jars of powder used in the geochemical analyses were used for isotopic analysis. Between 50 and 200 mg of sample powder were used, and in most cases (after spiking with $^{85}$Rb-$^{84}$Sr and $^{147}$Sm-$^{150}$Nd spike solutions) the powders were dissolved in open beakers. Exceptions are the differentiated samples from the Red Hill Dyke, and five contact sediments, which were dissolved in teflon bombs kept at ~200°C for 2 days.

In most cases, the samples were first dissolved in HF (~1ml), dried and redissolved using a further quantity of HF(conc) with a few drops of $HClO_4$(conc) added. This mixture was dried down and allowed to fume for at least an hour to remove any excess perchloric acid and fluorinated silicate. Having converted the fluorides to chlorates, ~2 ml of 6N HCl was added to convert the chlorates to chlorides. The solution was dried to stickiness and the residue re-dissolved in 2.5 ml of 1N HCl. The solution was then transferred to a labelled centifuge tube and spun down for several minutes.

These solutions were loaded onto 5 g cation exchange columns conditioned with 1N HCl. The Rb and Sr cuts from this column were dried and passed through 2 g clean-up columns, while the REE (collected in one cut) were dried and passed through pressurised columns using 0.2M methyl-lactic acid as the eluent. The Sm and Nd cuts were collected using an automatic rotating turntable linked to a drop-counter.

In addition to the spiked samples measured, twelve unspiked samples were dissolved to obtain Nd compositions of higher precision using the Finnigan-Mat 261 multiple collector mass spectrometer. These samples had been analysed previously (spiked) and an additional ~50 mg of each were processed in the manner described above. After removing the REE cuts from the 5g columns however, the samples were dried, redissolved in 0.2N HCl and passed through HDEHP columns.

For the spiked samples, the purified Rb, Sr, Sm and Nd cuts were run as the metal species using a rhenium triple-filament assemblage. The samples were loaded onto the side-filaments in distilled 1N HCl, and then analysed using the MSZ mass spectrometer (Clement and Compston, 1972). Data acquisition was performed automatically using programs developed at the ANU. The isotopic ratios were obtained by peak-switching and normalised to correct for mass fractionation ($^{86}Sr/^{88}Sr=0.1194$, $^{146}Nd/^{142}Nd=0.636151$). In general, 98 $^{87}Sr/^{86}Sr$ ratios, or 156 $^{143}Nd/^{144}Nd$ ratios are obtained for each particular analysis. No blank corrections were required for any of the ratios.

For the unspiked Nd analyses using the Finnigan-Mat multiple collector mass spectrometer, the intensities of the isotopes 142, 143, 144, 145, 146, and 150 are measured simultaneously. The samples were analysed twice (automatically) to examine how the reproducibility of the results compared with the precision calculated for individual runs. The automatic data acquisition program has been set up to collect 10 blocks of data per analysis, with 12 sets of ratios collected in each block. The precision and accuracy are discussed in Appendix 3.

## 2.7 DETERMINATION OF Pb ISOTOPIC COMPOSITIONS

Unlike the other isotopic analyses, the four samples chosen for Pb-isotopic analysis were processed using small chips of rock sample rather than the finely-crushed powders. A small piece of each hand-specimen was shattered in a Mg-steel piston assemblage, and interior fragments were hand-picked using clean tweezers. These chips (~0.5 g) were dissolved using HF and $HClO_4$ in teflon bombs and the residue converted to chlorides using 6N HCl. The solutions were split and a small portion spiked with mixed $^{235}U$-$^{208}Pb$ spike. The Pb was extracted from each split by passing the sample through 2 g Dowex-1 anion exchange columns using distilled solutions of HBr and HCl. The U was extracted from the spiked split by passing the dried cut (obtained from the 2 g columns) down teflon micro-columns using 10 N HCl, saturated ammonium sulphate solution, and ultra-pure water.

The unspiked Pb analyses were performed in duplicate (i.e. the Pb collected was loaded onto two separate filament beads) to check the reproducibility. Each aliquot of lead was loaded onto an outgassed single rhenium filament using silica-gel and phosphoric acid, and the U was loaded onto the same type of filament using a Ta-oxide slurry.

The main source of error in the Pb results is derived from variable mass fractionation and no correction for blank has been applied. Multiple analyses of NBS-981 were performed and a mass fractionation correction factor was derived by normalising the results to the corrected values of Catanzaro *et al.* (1968). The average correction factor obtained (based on 5 analyses of the standard) is 0.123% per mass unit.

## 2.8 DETERMINATION OF OXYGEN ISOTOPIC COMPOSITIONS

The technique employed in extracting the oxygen from each of 18 samples and converting it to $CO_2$ is similar to that described by Clayton and Mayeda (1963). Using this method, 15 mg of sample powder are weighed and carefully transferred into bombs under a back-pressure of Ar. An excess of $BF_5$ gas is measured into each of the 10 bombs which are then sealed from the rest of the line. Heating jackets are placed over the bombs and the samples are heated overnight (800°C).

The oxygen released from each digested sample is released into a chamber and converted to $CO_2$ by reaction with a heated carbon electrode. These $CO_2$ samples are removed from the line by freezing each one into a clean glass tube which is cut from the line with a oxy-acetylene torch.

The mass-spectrometry of the 18 samples analysed in this study was performed by Dr. A.R. Chivas and the results processed and normalised to standard mean ocean water (SMOW) using a computer program developed at ANU. Each gas sample was analysed in duplicate, and repeat analyses were performed using separate sample digestions for all samples. The $2\sigma$ uncertainties for the compositions obtained are less than or equal to ±0.3‰ and are listed beside the results in Appendix 5.

# APPENDIX 3.

## DETERMINATION OF ANALYTICAL PRECISION AND ACCURACY

In geochemical and isotopic research, a high level of accuracy in analytical results is important. To achieve this, laboratories make frequent analysis of international and in-house standards. This helps detect any technical problems, such as instrument drift or errors associated with a change in sample preparation.

The study of a rather homogeneous suite of samples requires that the data be of the highest precision possible. Only in this way can subtle differences in petrogenetic history be recognised and properly assessed.

Geochemical data published for dolerites from Tasmania indicate that the magmas emplaced in the Jurassic were of very uniform composition, at least with respect to the major elements (Edwards, 1942; McDougall, 1962). Also, despite the significant range in initial $^{87}Sr/^{86}Sr$ ratios, the Pb isotopic compositions show little variation, and two samples (showing a range in Sr-isotopic compositions) analysed for their Nd-isotopic signatures were identical within error (Allègre *et al.,* 1982).

The apparent homogeneity of the geochemical and isotopic compositions may either be real, or a result of poor precision of the measurements. To better evaluate these possibilities, it was considered important to determine the precision (as well as the accuracy) of the data obtained in this study

In order to determine the precision of individual (in the case of most of the isotopic data) or duplicate (in the case of the geochemical data) analyses, multiple measurements were made for particular samples. The standard deviation was then used to calculate the reproducibility expected for the other results. It is most useful to determine the precision using material of similar composition to the unknowns. For many trace elements, the chilled margin sample from Mt.Wellington (84-152) was chosen.

To evaluate the accuracy of measurements, international standards were analysed in triplicate (or more) and the averages compared to data available in the literature. In addition, the different analytical techniques employed in this study have facilitated a comparison between elemental data obtained by more than one method (e.g. Rb data obtained by XRF may be compared to the results from isotope dilution for the same samples).

Presentation of the results has been divided into two parts; the determination of precision and accuracy (subdivided into the geochemical and isotopic results), and the comparison between concentration data obtained by different instrumental techniques.

## 3.1 DETERMINATION OF ANALYTICAL PRECISION AND ACCURACY

### *3.1.1 Precision*

The precision of concentration measurements has been determined using a combination of the results obtained for W-2, and additional data obtained from the chilled margin dolerite 84-152, by calculating the standard deviation of multiple analyses. The precision of major element compositions is based on the eight analyses of W-2 (6 in the case of FeO wet-chemical analysis). Precision of the XRF trace element analyses has not been determined; however, the uncertainty associated with the INAA trace element data has been calculated using six separate analyses of 84-152. The results of these analyses are given in Table 3.1.

**Table 3.1** Six replicate analyses of chilled margin sample 84-152

| Element | 1 | 2 | 3 | 4 | 5 | 6 | Mean±σ | σ% | σ%/√2 |
|---|---|---|---|---|---|---|---|---|---|
| $Na_2O$ | 1.539 | 1.542 | 1.622 | 1.553 | 1.618 | 1.629 | 1.584±0.043 | 2.73% | 1.93% |
| Sc | 40.248 | 40.585 | 40.749 | 40.864 | 41.031 | 40.888 | 40.728±0.278 | 0.68% | 0.48% |
| Cr | 120.128 | 121.187 | 118.603 | 119.054 | 120.348 | 120.057 | 119.896±0.931 | 0.78% | 0.55% |
| Co | 63.116 | 64.451 | 64.492 | 64.198 | 65.242 | 63.753 | 64.209±0.722 | 1.12% | 0.80% |
| Cs | 1.274 | 1.343 | 1.359 | 1.332 | 1.499 | 1.233 | 1.340±0.091 | 6.80% | 4.81% |
| Ba | 233.685 | 240.681 | 251.990 | 233.123 | 240.468 | 209.355 | 234.884±14.2 | 6.06% | 4.29% |
| La | 10.711 | 10.428 | 10.889 | 10.802 | 10.879 | 10.908 | 10.770±0.183 | 1.69% | 1.20% |
| Ce | 23.959 | 24.532 | 24.737 | 25.714 | 25.352 | 24.116 | 24.735±0.688 | 2.78% | 1.97% |
| Nd | 12.022 | 12.479 | 12.958 | 13.140 | 12.512 | 12.189 | 12.550±0.431 | 3.44% | 2.43% |
| Sm | 3.051 | 3.014 | 3.041 | 3.090 | 3.134 | 3.112 | 3.074±0.046 | 1.49% | 1.06% |
| Eu | 0.808 | 0.816 | 0.821 | 0.823 | 0.833 | 0.811 | 0.819±0.009 | 1.11% | 0.78% |
| Gd | 3.100 | 3.521 | 2.995 | 3.259 | 3.345 | 3.029 | 3.208±0.204 | 6.36% | 4.50% |
| Tb | 0.573 | 0.538 | 0.576 | 0.600 | 0.654 | 0.536 | 0.580±0.044 | 7.58% | 5.36% |
| Ho | 0.819 | 0.795 | 0.755 | 0.876 | 0.866 | 0.855 | 0.828±0.047 | 5.66% | 4.00% |
| Yb | 2.551 | 2.163 | 2.292 | 2.306 | 2.293 | 2.350 | 2.326±0.127 | 5.45% | 3.86% |
| Lu | 0.363 | 0.350 | 0.362 | 0.365 | 0.364 | 0.359 | 0.361±0.006 | 1.54% | 1.09% |
| Hf | 1.786 | 1.850 | 1.863 | 2.054 | 2.012 | 1.782 | 1.891±0.115 | 6.10% | 4.31% |
| Ta | 0.520 | 0.515 | 0.517 | 0.562 | 0.535 | 0.537 | 0.531±0.018 | 3.35% | 2.37% |
| Th | 3.882 | 3.685 | 3.728 | 3.369 | 3.327 | 3.412 | 3.567±0.228 | 6.39% | 4.52% |
| U | 1.166 | 1.059 | 1.170 | 1.161 | 1.294 | 1.181 | 1.172±0.075 | 6.37% | 4.51% |

$Na_2O$ as per cent. and other elements as ppm.

σ and σ% are the standard and relative standard errors of individual measurements.

σ%/√2 is relative standard error of two measurements, i.e. a duplicated analysis.

For Ba, Ce, Nd, Tb and Hf data would be improved by use of a larger detector for count 3 (see footnote to Table 2.1). These analyses are all of the same sample and assume a fixed FeO value (8.77%) and hence errors in the XRF measurement of FeO are not a component in the above data; this would have a slight effect only for Sc, Cr and Eu so that these figures are also good estimates of precision when different samples are measured.

For twenty elements, this table shows the mean and the standard deviation of individual measurements and the coefficient of variation (σ%/√2). The coefficient of variation divided by √2 is also shown since this is the estimate of the error in a duplicated analysis, as made on all other chilled margin samples. The maximum value of $\sigma\%/\sqrt{2}$ is 5.36% (Tb), for nine elements it is less than two per cent. and for Sc, Cr Co and Eu it is below one per cent.

The errors shown in Table 3.1 are in general much better than those normally claimed for the INAA method. For example, in the study of precision of a sample of Whin Sill basalt, Potts *et al.* (1985) found that "For many elements coefficients of variation lie in the range 2-5% ($1\sigma$) which we consider to be excellent for INAA".

As mentioned above, all XRF and INAA analyses of unknowns were performed in duplicate and therefore the uncertainty is given by $\sigma/\sqrt{2}$. The calculated analytical precision (based on duplicate analyses) for the unknowns is listed in Table 3.2.

**Table 3.2** Estimated precision (in percent) for the chilled margin analyses. Uncertainties in the major element XRF data have been calculated using multiple analyses of W-2. The precision of the elements obtained from INAA are from Table 2.1.

| | | | | | |
|---|---|---|---|---|---|
| $SiO_2$ | 0.3 | Cs | 4.8 | Th | 4.5 |
| $TiO_2$ | 0.8 | La | 1.2 | U | 4.5 |
| $Al_2O_3$ | 0.3 | Ce | 2.0 | Hf | 4.3 |
| $Fe_2O_3$ | 0.2 | Nd | 2.4 | Sc | 0.5 |
| FeO | 0.5 | Sm | 1.1 | S | 16.5 |
| MnO | 1.1 | Eu | 0.8 | | |
| MgO | 0.6 | Gd | 4.5 | | |
| CaO | 0.3 | Tb | 5.4 | | |
| $Na_2O$ | 1.3 | Ho | 4.0 | | |
| $K_2O$ | 0.9 | Yb | 3.9 | | |
| $P_2O_5$ | 1.9 | Lu | 1.1 | | |

### *3.1.2 Accuracy*

The accuracy of the data produced by XRF and INAA in the Geology Department laboratory at ANU was expected to be high as a close check is maintained by frequent analysis of in-house standards (which have been carefully calibrated against well documented international standards such as BCR-1). Nevertheless, this has been quantified by multiple analysis of the international standard W-2.

The composition of W-2 may not be as well known as some other standards, and although it compares well with the original standard W-1 (Flanagan, 1984) many of the results for W-1 were produced prior to the improvements in instrumentation now available. Despite this, a recent compilation of data for W-2 by Flanagan (1984) includes data from up to 25 laboratories and is expected to provide a good estimate of W-2 with which to assess the accuracy of our results. The major advantage of using W-2 is that the chemical composition of this standard is close to that of the chilled margins analysed from Tasmania.

Eight separate preparations of W-2 were fused into glass discs for major element analysis (the oxidation state of Fe in W-2 was determined by 6 dissolutions of rock powder followed by titration, see Appendix 2). The trace elements Ba, Rb, Sr, Pb, Y, V, Cr, Mn, Ni, Cu, Zn and Ga have been obtained by triplicate analysis of pressed powder pellets.

The accuracy of the INAA data has been determined by including one W-2 sample in each of 6 different irradiation batches. Although these results could also have been used to determine the analytical precision, the Mt. Wellington chilled margin sample 84-152 was included in each of six batches and has been used for this purpose since it is even closer to the average chilled margin in composition. The average composition for W-2 is presented in Table 3.3.

A number of important points are indicated from the results. The agreement between the compositions of W-2 obtained from this study, and the compilation of Flanagan (1984) is generally very close (Table 3.3); however, the few exceptions include Cs, Ho, Hf and V. Comparison with the original data used by Flanagan (1984) indicates that of the 9 laboratories reporting Cs data, 8 obtained values of Cs≥ 0.9 ppm. Similarly, the concentration of Hf in W-2 from each of the 10 sources listed (Flanagan, 1984) is greater than 2.35 ppm. It appears that our results for Hf, and possibly Cs, are genuinely in error (owing to unrecognised spectral interferences?).

Very little Ho data are available for W-2, and the three sources reported in Flanagan (1984) give mean values of 0.62, 0.71 and 1.26 ppm. The Ho value from this study is between the larger of these two values and is therefore considered to be in agreement.

The data compiled by Flanagan for V from different sources indicates some complication with the analysis of this element and a wide range in values has been obtained from different laboratories (128-440 ppm). The mean value estimated by Flanagan of 258.8 ppm is reasonable when the entire data set is considered in a broad sense. The 100 individual analyses listed have been divided into 10 ppm intervals and plotted against the frequency (Fig. 3.1). Clearly, the peak in the data at 250-260 ppm (indicated by the column labelled 255) is consistent with a mean value of ~259 ppm. However, if the data are divided into 5 ppm intervals, the bell-shaped distribution between ~255 and 285 ppm appears to split with the main peak at approximately 245-255 ppm and a second peak at ~260-270 ppm (Fig. 3.1, inset). It may be fortuitous that few labs report data between these groups and that the true mean is close to ~259 ppm; however, the resolution of this problem requires further careful analysis.

The V content of ~240 ppm obtained in this study appears to be too low even if a bimodal distribution is assumed and the range ~245-255 ppm preferred.

In addition, the difference in the Cr value is also surprisingly large (see later comparison between XRF and INAA results for this element).

**Table 3.3** Average composition of W-2 obtained in this study compared with the compilation of Flanagan (1984). The $2\sigma_{mean}$ is listed for each elemental concentration. The number of individual analyses performed in this study (n) and the number of laboratory means used in the compilation of Flanagan (n) are also given. Major element oxides are in wt.% and trace elements are in ppm.

| | W-2 | $2\sigma_{mean}$ | n | W-2 | $2\sigma_{mean}$ | n |
|---|---|---|---|---|---|---|
| | (this study) | | | (Flanagan, 1984) | | |
| $SiO_2$ | 53.21 | 0.166 | 8 | 52.68 | 0.58 | 18 |
| $TiO_2$ | 1.09 | 0.010 | 8 | 1.062 | 0.026 | 19 |
| $Al_2O_3$ | 15.48 | 0.054 | 8 | 15.45 | 0.32 | 17 |
| $Fe_2O_3$ | 1.57 | 0.022 | 8 | 1.53 | 0.174 | 6 |
| FeO | 8.32 | 0.036 | 8 | 8.34 | 0.186 | 6 |
| MnO | 0.16 | 0.002 | 8 | 0.167 | 0.008 | 20 |
| MgO | 6.53 | 0.043 | 8 | 6.37 | 0.116 | 13 |
| CaO | 11.11 | 0.037 | 8 | 10.86 | 0.156 | 11 |
| $Na_2O$ | 2.17 | 0.035 | 8 | 2.20 | 0.074 | 17 |
| $K_2O$ | 0.65 | 0.007 | 8 | 0.626 | 0.024 | 20 |
| $P_2O_5$ | 0.13 | 0.003 | 8 | 0.141 | 0.232 | 18 |
| Cs | 0.78 | 0.04 | 6 | 1.01 | 0.32 | 5 |
| Ba | 174.13 | | 3 | 173.6 | 22.6 | 10 |
| Rb | 19.17 | | 3 | 19.9 | 2.12 | 11 |
| Sr | 193.47 | | 3 | 191.9 | 5.96 | 8 |
| Pb | 7.53 | | 3 | 7.66 | | 1 |
| La | 9.91 | 0.09 | 6 | 10.36 | 1.18 | 12 |
| Ce | 23.5 | 0.6 | 6 | 23.37 | 2.94 | 10 |
| Nd | 13.4 | 0.6 | 6 | 13.36 | 2.1 | 4 |
| Sm | 3.39 | 0.06 | 6 | 3.31 | 0.252 | 7 |
| Eu | 1.139 | 0.004 | 6 | 1.12 | 0.12 | 11 |
| Gd | 3.59 | 0.07 | 6 | 3.9 | | 2 |
| Tb | 0.65 | 0.04 | 6 | 0.66 | 0.364 | 6 |
| Ho | 0.84 | 0.06 | 6 | 0.68 | 0.226 | 2 |
| Yb | 2.13 | 0.06 | 6 | 2.14 | 0.32 | 11 |
| Lu | 0.318 | 0.007 | 6 | 0.33 | 0.14 | 8 |
| Y | 19.75 | | 3 | 23.4 | 3.26 | 7 |
| Th | 2.2 | 0.2 | 6 | 2.41 | 0.24 | 8 |
| U | 0.45 | 0.06 | 6 | 0.49 | 0.12 | 5 |
| Zr | | | | 96.2 | 7.48 | 6 |
| Hf | 1.94 | 0.05 | 6 | 2.60 | 0.356 | 8 |
| Nb | | | | 6.75 | 0.84 | 4 |
| Sc | 35.5 | 0.2 | 6 | 35.7 | 2.12 | 9 |
| V | 237.6 | | 3 | 258.8 | 24.54 | 13 |
| Cr | 81.7 | | 3 | 91.51 | 8.9 | 19 |
| Mn | 1296.3 | | 3 | | | |
| Ni | 69.1 | | 3 | 71.8 | 4.92 | 10 |
| Cu | 100.0 | | 3 | 106.2 | 9.76 | 10 |
| Zn | 76.79 | | 3 | 78.8 | 4.56 | 10 |
| Ga | 17.91 | | 3 | 16.8 | 1.78 | 4 |

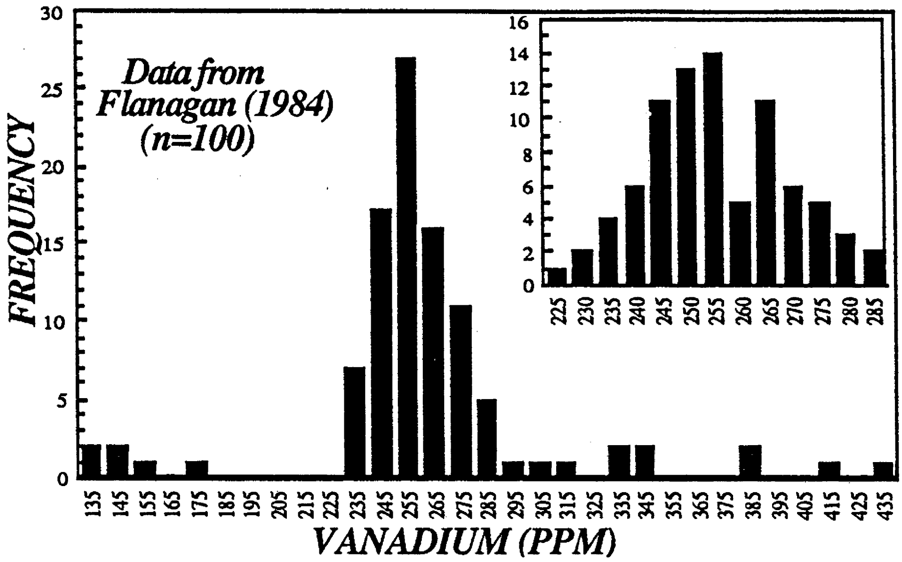


Fig. 3.1 Histogram illustrating the variation in V contents and their observed frequency for W-2 reported in Flanagan (1984). The data have been divided into 10 ppm intervals and indicate that at this scale the mean value lies in the interval 250-260 ppm. The inset (in which the concentrations are divided into 5 ppm intervals) illustrates that at a finer scale, the data may follow an almost bimodal distribution. In this case, the concentration of V is best represented by a mean either in the range 245-255 ppm, or 260-270 ppm.

### *3.1.3. Isotopic Data*

An estimate of the precision and accuracy of the isotopic results has been achieved by several means. The errors associated with the Pb and O results are discussed in Appendix 2. This section deals with the Rb-Sr and Sm-Nd results which constitute the major proportion of the isotopic data. All but twelve of the sample dissolutions were performed on spiked samples and this section deals with the precision and accuracy of the concentration data as well as the isotopic ratios.

Analyses of various standard solutions during the period in which the data for the unknowns were obtained are listed in Table 3.4. These results were obtained jointly by all users of the MSZ mass spectrometer and do not represent my own work. The data are consistent with values reported in the literature. Analysis of these solutions is the predominant means by which a check of the accuracy of results is maintained. This is important if the running-conditions or hardware of the instrument are varied (e.g. McDonough et al., 1985).

**Table 3.4** Compilation of analyses (of standard solutions) obtained during the collection of data on unknowns in this study. These results are a combination of analyses performed by the six operators of the MSZ in this period.

| Standard | $^{87}Sr/^{86}Sr$ | n | $^{143}Nd/^{144}Nd$ | n |
|---|---|---|---|---|
| NBS 987 | 0.71028±3 | 18 | | |
| E&A | 0.70801±1 | 11 | | |
| Ndα | | | 0.511080±15 | 9 |
| La Jolla | | | 0.511025±07 | 4 |

In addition to the standard solutions, the international basalt standard BHVO-1 was dissolved and analysed in triplicate. Each dissolution was spiked to compare the reproducibility of the elemental concentrations as well as the isotopic compositions. The results are listed in Table 3.5 and are compared with values reported in the literature.

The isotopic compositions are identical to the results of White and Hofmann (1982) within the in-run analytical uncertainties. The concentration data (particularly the Sm and Nd results) are also close to reported values, although the Sr concentrations obtained in this study appear to be low. The range of values in the compilation of Abbey (1983) for Rb and Sr indicate that these lower values can be accommodated within the uncertainty. It will be shown in the next section that the concentration data obtained by isotope dilution is in excellent agreement with the results obtained using other techniques (shown previously to be accurate to within precision estimates for Rb, Sr, Sm and Nd by comparison with W-2).

**Table 3.5** Compilation of 3 separate dissolutions of the basalt standard BHVO-1. Concentrations are in ppm, errors in individual analyses represent the $2\sigma$ in-run precision. The mean of the analyses is given together with the $2\sigma_{mean}$. Reported values for the elemental concentrations are from Abbey (1983) and the isotopic compositions are from White and Hofmann (1982). Note: The average Nd isotopic composition from this study has been recalculated normalised to $^{146}Nd/^{144}Nd=0.72190$ to facilitate the comparison.

| Rb | Sr | $^{87}Rb/^{86}Sr$ | $^{87}Sr/^{86}Sr$ | Sm | Nd | $^{147}Sm/^{144}Nd$ | $^{143}Nd/^{144}Nd$ |
|---|---|---|---|---|---|---|---|
| 8.8 | 380.1 | 0.067 | 0.70352 ±2 | 6.14 | 24.75 | 0.1500 | 0.512155 ±24 |
| 8.9 | 383.7 | 0.067 | 0.70347 ±4 | 6.14 | 24.75 | 0.1499 | 0.512165 ±42 |
| 9.4 | 393.7 | 0.069 | 0.70347 ±4 | 6.24 | 25.28 | 0.1493 | 0.512128 ±26 |
| Average of three analyses (± $2\sigma_{mean}$): | | | | | | | |
| 9.0 | 385.8 | 0.068 | 0.70349 | 6.17 | 24.93 | 0.1497 | 0.512149 |
| ±0.3 | ±6.6 | ±0.001 | ±0.00003 | ±0.05 | ±0.29 | ±0.0004 | ±0.000018 |
| | | | | | (recalculated value =0.512974) | | |
| Reported values (± $2\sigma$ in-run precision): | | | | | | | |
| 10 | 420 | | 0.70346 ±2 | 6.1 | 24 | | 0.512948 ±13 |
| | | | 0.70345 ±5 | | | | 0.512990 ±24 |

It is apparent that the reproducibility and accuracy of the isotopic compositions measured on the MSZ are within the $2\sigma$ in-run precision of individual analyses.

The Nd compositions for chilled margin dolerites analysed on the MSZ are considered to be the same within error, although it was thought that some analyses appear to be close to the limit of this uncertainty and may show subtle variation if the uncertainties were reduced. To examine this possibility, 12 unspiked Nd samples were run on the multiple-collector mass spectrometer to improve the precision. Each sample was analysed using the automatic data acquisition program, and the samples which were not exhausted were re-run.

The results are given in Table 3.6 and indicate that the $2\sigma$ in-run precision obtained for individual analyses is close to the reproducibility. The accuracy of the results was examined by comparison of various standards (run by a number analysts) with the results obtained for the MSZ spectrometer. To make the comparison it was necessary to re-normalise the isotopic ratios because the correction for mass-fractionation used on the MSZ is $^{146}Nd/^{142}Nd=0.636151$, compared with $^{146}Nd/^{144}Nd=0.72190$ on the MAT. This was achieved by multiplying the MSZ data by a factor of 1.001596 (derived by dividing the average BCR-1 $^{143}Nd/^{144}Nd$ ratio obtained from the MAT by that from the MSZ). The results are compared in Table 3.7 and indicate that there is a systematic offset in the ratios obtained from each spectrometer, with the MAT giving values consistently higher than the MSZ. This off-set is illustrated by the $\varepsilon_{Nd}$ values calculated for the standards BHVO-1 and La Jolla relative to the bulk-earth Nd composition (given by the mean BCR-1 value for each instrument). If there were random differences between the two mass spectrometers, the calculated $\varepsilon_{Nd}$ values for BHVO-1 and La Jolla should not coincide; reference to Table 3.7 indicates that this is not the case, and the values for these standards are identical within the estimated error.

**Table 3.6** Comparison between the reproducibility and 2σ in-run precision of Nd analyses obtained from the MAT 261 multiple collector mass spectrometer.

| Sample Number ($\pm 2\sigma_{mean}$) | $^{143}Nd/^{144}Nd$ ($\pm 2\sigma$) RUN 1 | $^{143}Nd/^{144}Nd$ ($\pm 2\sigma$) RUN 2 | $^{143}Nd/^{144}Nd$ MEAN |
|---|---|---|---|
| 84-108 | 0.512325 ±5 | 0.512313 ±6 | 0.512319 ±9 |
| 84-109 | 0.512324 ±5 | 0.512310 ±9 | 0.512317 ±10 |
| 84-129 | 0.512322 ±5 | 0.512335 ±7 | 0.512329 ±9 |
| 84-141 | 0.512320 ±5 | 0.512312 ±11 | 0.512316 ±6 |
| 84-144 | 0.512330 ±5 | 0.512324 ±8 | 0.512327 ±5 |
| 84-149 | 0.512331 ±6 | | |
| 84-169 | 0.512344 ±7 | 0.512332 ±6 | 0.512338 ±9 |
| 84-170 | 0.512325 ±8 | 0.512330 ±6 | 0.512328 ±4 |
| 84-203 | 0.512334 ±8 | 0.512324 ±5 | 0.512329 ±7 |
| 84-205 | 0.512335 ±8 | 0.512318 ±5 | 0.512327 ±12 |
| 84-221 | 0.512333 ±5 | | |
| 84-222 | 0.512328 ±5 | | |

**Table 3.7** Comparison between the $^{143}Nd/^{144}Nd$ results for standards using the MAT and MSZ spectrometers. The number of analyses used for each mean is given in parenthesis. Ratios obtained using the MAT are systematically higher by 0.062-0.088 ‰. This deviation is removed by calculating the $\varepsilon_{Nd}$ values using the mean BCR-1 value from each instrument as a measure of the present-day bulk earth Nd composition.

| Standard | $^{143}Nd/^{144}Nd \pm 2\sigma_{mean}$ MAT | $^{143}Nd/^{144}Nd \pm 2\sigma_{mean}$ MSZ | Difference in ‰ MAT - MSZ |
|---|---|---|---|
| BCR-1 | 0.512653 ±5 (7) | 0.512608 ±10 (7) | 0.088 |
| BHVO-1 | 0.512999 ±5 (1) | 0.512967 ±17 (3) | 0.062 |
| La Jolla | 0.511873 ±5 (17) | 0.511841 ±7 (4) | 0.063 |

Using the BCR-1 mean obtained from each instrument as a measure of present-day CHUR:

| | $\varepsilon_{Nd}$ | $\varepsilon_{Nd}$ |
|---|---|---|
| BHVO-1 | 6.75 ±0.14 | 7.00 ±0.39 |
| La Jolla | -15.22 ±0.14 | -14.96 ±0.24 |

## 3.2 COMPARISON BETWEEN CONCENTRATION DATA OBTAINED BY DIFFERENT INSTRUMENTAL TECHNIQUES (XRF, INAA AND ID)

Various techniques have been employed to obtain a wide range of elemental and isotopic data and include XRF spectrometry, INAA, and isotope dilution mass spectrometry (ID). The concentrations of a few elements have been determined independently by more than one technique, providing a useful means for comparing the accuracy of different instrumental methods.

The following comparison is based on chilled margin dolerites and selected samples from differentiated intrusions, as these were analysed in the most detail. Most of the diagrams used in the discussion contain 67 data points; however, the plots using data obtained by ID contain less points owing to the smaller number of samples analysed by this technique. All figures include a 1:1 ratio reference line to illustrate the correlation expected in the ideal case where the values obtained by different methods are identical.

Figure 3.2 compares some of the major element data obtained by XRF and INAA. The $Na_2O$ results from the two techniques show a linear relationship which is offset from the reference line. The values obtained by XRF analysis are consistently high relative to the INAA data. This is likely to be the result of a small difference in the calibration of the instruments as the offset is systematic.

In contrast, the CaO data from XRF and INAA agree closely and indicate that the results are likely to be accurate from both techniques. The third diagram in Figure 3.2 illustrates the correlation between the MnO contents of 67 samples measured by different XRF techniques (note that most points overlap each other giving the false impression that only 9 points are plotted). As well as measuring MnO as a major element, the Mn content is determined as a trace element by analysis of pressed powder pellets. The trace elemental abundances (in ppm) have been recalculated as oxides and the comparison illustrated indicates that excellent agreement is obtained.

Other trace elements analysed by both XRF and INAA include Ce, La, Cr and Ba. The four diagrams of Figure 3.3 indicate that agreement is generally good, particularly in the case of La and Ce. Cr by INAA shows a small but consistent offset to higher values, whereas the Ba data from INAA are systematically low compared with the XRF results. This does not seriously effect the results below approximately 300 ppm, but does become an increasing problem at higher Ba contents.

Figure 3.4 compares the Sr and Rb data obtained by XRF and ID. The results from XRF and ID compare very well and plot close to the reference lines. It was shown previously that the Rb and Sr data from XRF are accurate (using W-2), and that the ID data from BHVO-1 are also close to reported values. The excellent agreement between the results shown in Figure 3.4 supports this conclusion. These results indicate that despite the increased precision obtained using ID, the accuracy is probably similar for both XRF and ID.

Finally, the Sm and Nd contents determined by INAA and ID are compared in Figure 3.5. Most of the data plot on or very close to the 1:1 reference lines with 3 points plotting one or two ppm away.

Comparisons such as those made in Figures 3.2 to 3.5 increase our confidence in the accuracy of the data obtained by independent analytical techniques, particularly where the instruments have been calibrated using different methods (e.g. the original calibration for Cr was performed using spec-pure chemicals for the XRF spectrometer, compared with W-1 for INAA). Concentration data obtained by ID has confirmed the accuracy of the XRF and INAA results. Conversely, the XRF and INAA results have enabled the constant monitoring of the spike solutions used in the isotopic measurements.

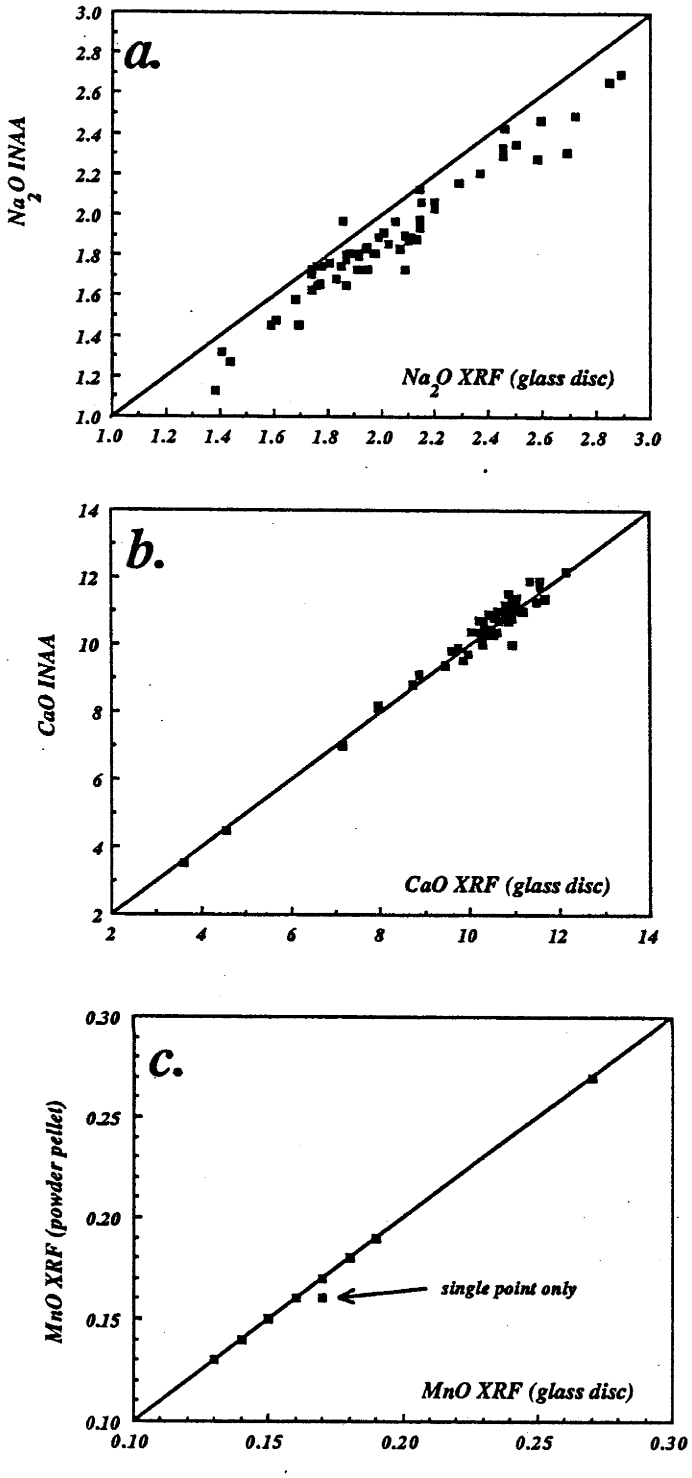


**Fig. 3.2** Comparison between major element compositions obtained by different analytical techniques. **a.** $Na_2O$ from INAA and XRF. **b.** CaO from INAA and XRF. **c.** MnO measured by XRF both as a major element oxide (glass disc) and trace element (as ppm Mn, recalculated for this comparison).

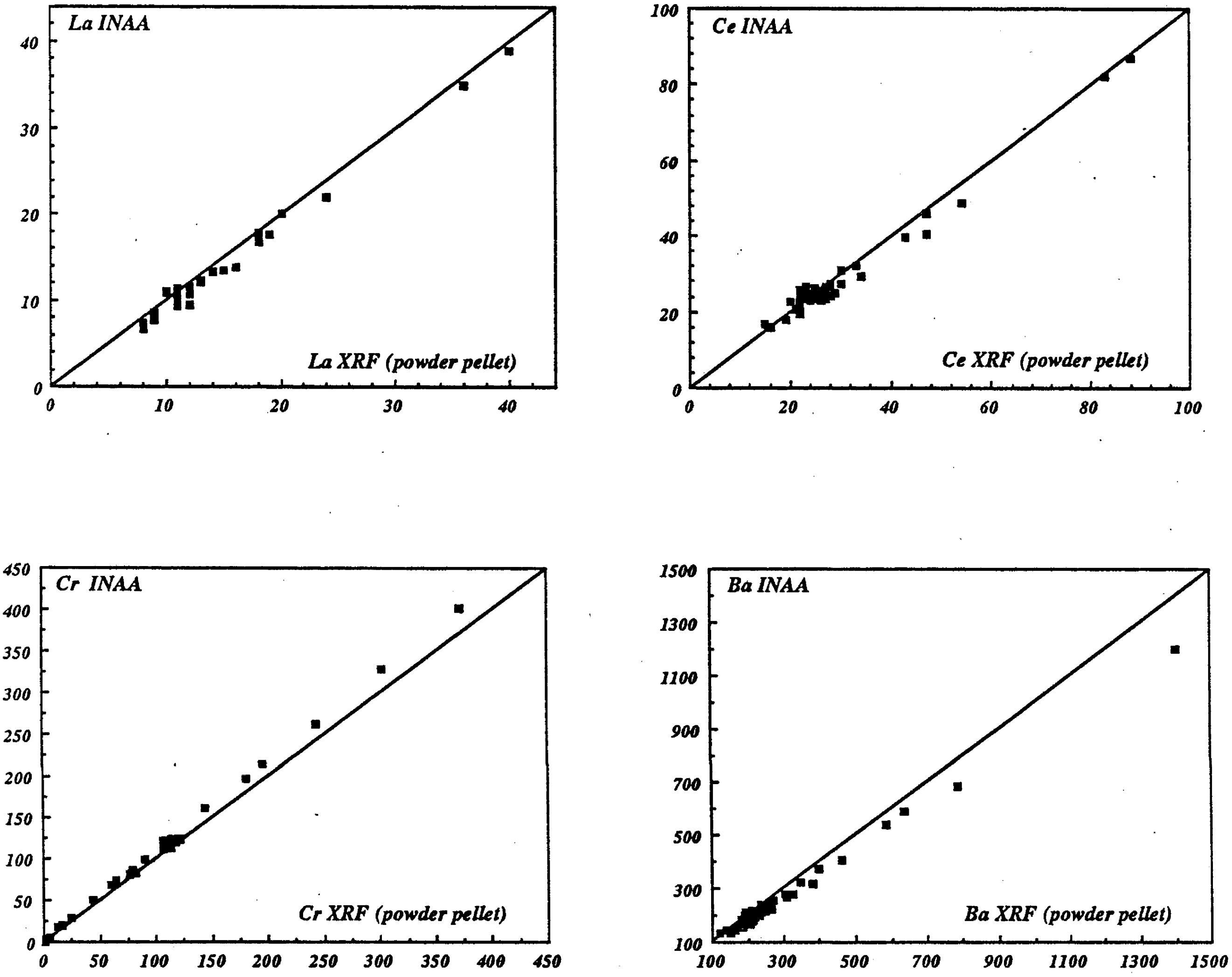
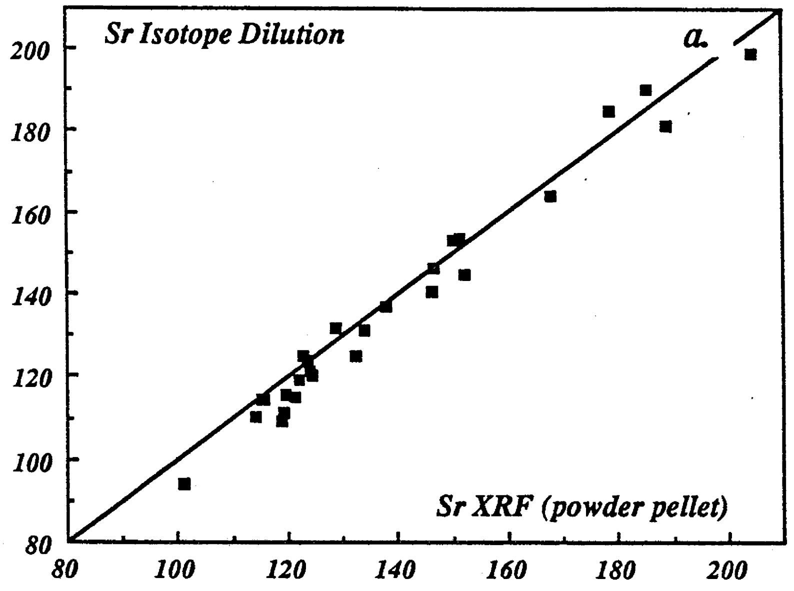


Fig. 3.3. Comparison between Ce, La, Cr and Ba data obtained by XRF and INAA.



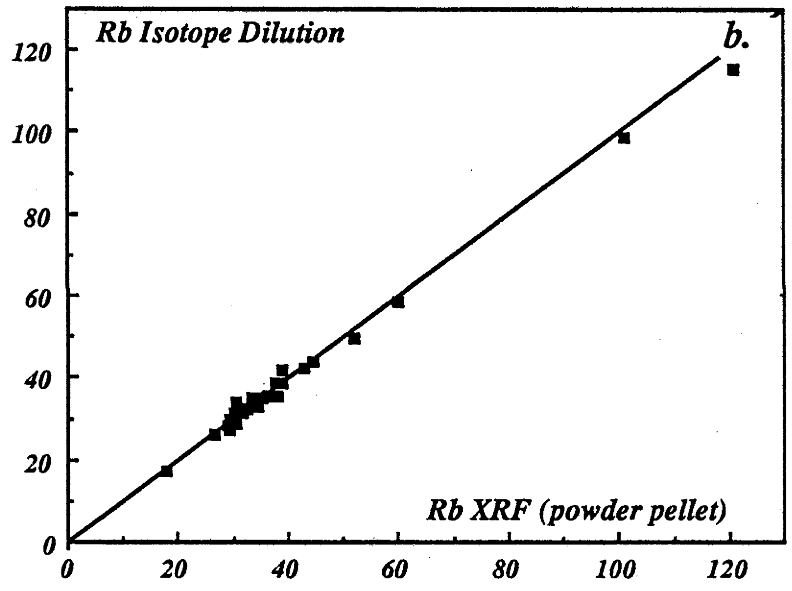
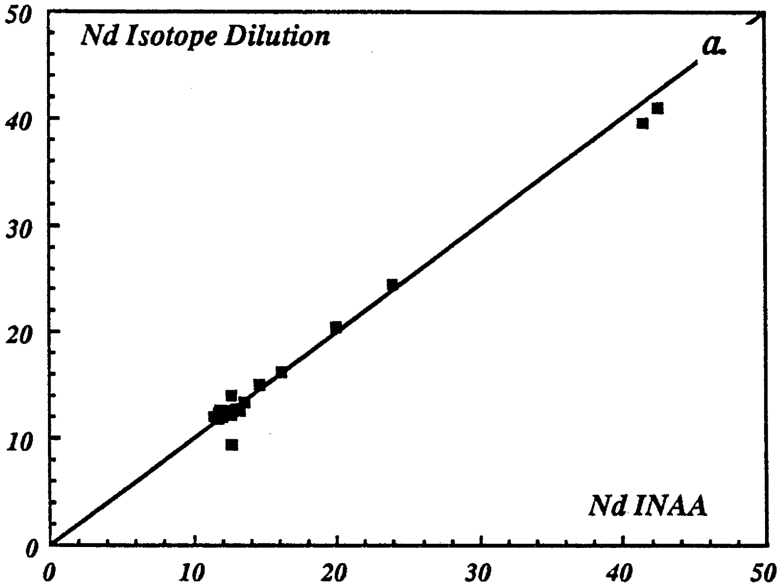


**Fig. 3.4** Comparison between Sr (a.) and Rb (b.) data obtained using XRF and ID.



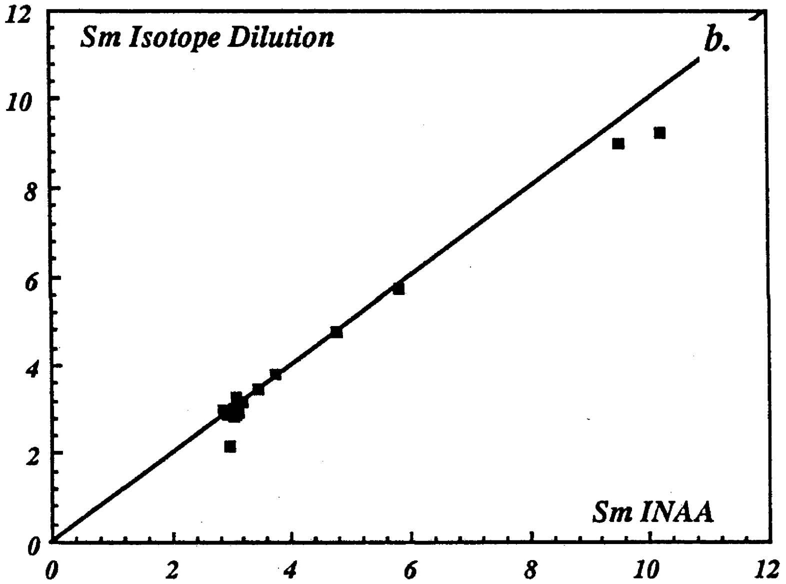


**Fig. 3.5** Comparison between REE data obtained by ID and INAA. **a.** Nd from ID versus INAA. **b.** Sm from ID versus INAA.

# APPENDIX 4.

## GEOCHEMICAL DATABASE

The geochemical data compiled in this appendix are divided into three sections. The first section includes all of the geochemical data obtained on samples collected from Tasmania and constitutes the major proportion of the results. The second section of the appendix contains the analyses of samples from Portal Peak (Antarctica). Finally, the third part of the compilation lists the data obtained on samples related to the Tasmanian Dolerites occurring in western Victoria and Kangaroo Island. The powders remaining from the analytical work, as well as the thin-sections and rock specimens are retained in the A.N.U Research School of Earth Sciences collection.

### 4.1 TASMANIAN SAMPLES

The data from the Tasmanian specimens are subdivided into three sections. The major and trace element X-ray fluorescence spectrometric (XRF) data and wet-chemical results from Tasmanian samples are presented in order of increasing catalogue number in the first section of this part of the appendix. The results include analyses of sediments in direct contact with the chilled margin dolerites in a few localities. These samples were chosen as representative of the dominant country-rock material in contact with the dolerite and include arkosic sandstones and fossiliferous marls of the Parmeener Supergroup (Permo-Triassic). The dolerites include the 37 chilled margin samples and the many dolerites sampled from measured sections through intrusions.

Over 60 of the samples included in the first compilation were selected for more detailed analysis using instrumental neutron activation analysis (INAA). These additional results (combined with the data listed in the first compilation) are located at the end of this section. These more detailed data sets are divided into two parts; the first part contains the data for the chilled margin samples and provides the basis for the discussion in Chapter 4, the second part contains the data for measured sections through intrusive bodies used to investigate the differentiation history of the Tasmanian Dolerites (Chapter 3). Although the organisation of the data in this manner necessarily duplicates some of the results, this seems justified by the benefit of being able to refer to the particular group of results discussed in the text.

### 4.2 PORTAL PEAK SAMPLES

The XRF and wet-chemical data obtained on the suite of samples from Portal Peak are listed in order of increasing catalogue number (the original field numbers assigned by Prof. Gunter Faure and Teresa Mensing have also been included). Six of the samples were chosen for analysis by INAA and the results are located at the end of this section of the appendix.

## 4.3 VICTORIAN AND KANGAROO ISLAND SAMPLES

These 7 samples have been analysed for major elements by XRF and wet-chemical techniques, and trace elements by Spark Source Mass Spectrometry. The combined results are located in this section and are listed in order of increasing catalogue number.

# 4.1 DATABASE OF TASMANIAN SAMPLES

# XRF AND WET-CHEMICAL ANALYSES OF CHILLED AND DIFFERENTIATED DOLERITES AS WELL AS COUNTRY-ROCKS SAMPLED FROM CONTACTS

| | **84 101** | **84 102** | **84 103** | **84 104** | **84 105** | **84 106** | **84 107** |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 54.42 | 53.66 | 62.91 | 67.29 | 72.15 | 54.00 | 53.73 |
| $TiO_2$ | 0.63 | 0.56 | 1.26 | 0.83 | 0.30 | 0.63 | 0.63 |
| $Al_2O_3$ | 14.54 | 16.76 | 10.86 | 11.09 | 13.80 | 14.69 | 14.60 |
| $Fe_2O_3$ | 0.86 | 1.88 | 5.90 | 3.51 | 1.47 | 1.03 | 1.47 |
| FeO | 7.99 | 7.45 | 6.22 | 5.32 | 0.45 | 7.83 | 7.53 |
| MnO | 0.17 | 0.17 | 0.18 | 0.14 | 0.02 | 0.19 | 0.19 |
| MgO | 6.68 | 4.41 | 0.53 | 0.20 | 0.53 | 6.71 | 6.78 |
| CaO | 11.05 | 10.70 | 4.54 | 3.60 | 0.99 | 10.69 | 10.59 |
| $Na_2O$ | 1.99 | 2.13 | 2.59 | 2.89 | 7.88 | 2.15 | 2.09 |
| $K_2O$ | 0.60 | 0.80 | 2.67 | 3.08 | 1.79 | 0.85 | 0.83 |
| $P_2O_5$ | 0.09 | 0.09 | 0.38 | 0.19 | 0.11 | 0.09 | 0.09 |
| S | 0.04 | 0.03 | 0.06 | 0.05 | 0.02 | 0.03 | 0.03 |
| $H_2O+$ | 0.93 | 1.08 | 1.18 | 0.97 | 0.52 | 0.62 | 0.80 |
| $H_2O-$ | 0.26 | 0.26 | 0.47 | 0.70 | 0.29 | 0.53 | 0.68 |
| $CO_2$ | 0.20 | 0.08 | 0.46 | 0.18 | 0.11 | 0.16 | 0.15 |
| rest | 0.15 | 0.13 | 0.18 | 0.19 | 0.09 | 0.15 | 0.15 |
| | 100.60 | 100.19 | 100.39 | 100.23 | 100.52 | 100.35 | 100.34 |
| O=S | 0.02 | 0.02 | 0.03 | 0.02 | | 0.01 | 0.01 |
| Total | 100.58 | 100.17 | 100.36 | 100.21 | 100.52 | 100.34 | 100.33 |
| | | | | | | | |
| Ba | 190 | 195 | 585 | 635 | 165 | 205 | 200 |
| Rb | 17.8 | 29.5 | 101.0 | 121.0 | 33.5 | 30.6 | 29.3 |
| Sr | 132.2 | 154 | 114 | 101 | 102 | 121.4 | 119.0 |
| Pb | 7 | 5 | 16 | 17 | 14 | 5 | 6 |
| La | 11 | 10 | 36 | 40 | 18 | 11 | 10 |
| Ce | 24 | 23 | 83 | 88 | 39 | 23 | 24 |
| Y | 21.1 | 19 | 59 | 59 | 10 | 20.3 | 20.7 |
| Th | 4.0 | 2.0 | 13.0 | 14.0 | 9.0 | 4.0 | 3.0 |
| U | 3.0 | 1.0 | 6.0 | 2.0 | 1.0 | 2.0 | 1.0 |
| Zr | 94 | 84 | 273 | 334 | 179 | 94 | 96 |
| Nb | 4.0 | 3.0 | 14.5 | 16.0 | 4.5 | 5.0 | 4.5 |
| V | 223 | 215 | 1 | 1 | 41 | 231 | 221 |
| Cr | 113 | 3 | 1 | 1 | 34 | 121 | 112 |
| Mn | 1340 | 1300 | 1370 | 1060 | 155 | 1450 | 1470 |
| Ni | 79 | 40 | 3 | 1 | 9 | 83 | 80 |
| Cu | 78 | 153 | 37 | 19 | 3 | 79 | 75 |
| Zn | 82 | 78 | 128 | 111 | 27 | 80 | 78 |
| Ga | 16.0 | 18.0 | 19.5 | 18.0 | 14.5 | 15.5 | 16.0 |

| | **84 108** | **84 109** | **84 110** | **84 111** | **84 112** | **84 113** | **84 114** |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 54.02 | 54.43 | 54.40 | 53.99 | 55.24 | 54.51 | 54.17 |
| $TiO_2$ | 0.63 | 0.66 | 0.66 | 0.64 | 0.83 | 0.63 | 0.61 |
| $Al_2O_3$ | 14.66 | 14.42 | 14.41 | 14.66 | 13.40 | 14.84 | 14.67 |
| $Fe_2O_3$ | 1.19 | 1.59 | 1.57 | 1.22 | 1.96 | 1.61 | 1.25 |
| FeO | 7.70 | 7.60 | 7.51 | 7.59 | 8.83 | 7.31 | 7.47 |
| MnO | 0.18 | 0.18 | 0.17 | 0.17 | 0.19 | 0.17 | 0.17 |
| MgO | 6.78 | 6.46 | 6.35 | 6.83 | 5.24 | 6.66 | 6.83 |
| CaO | 10.53 | 10.04 | 10.23 | 10.32 | 9.63 | 10.66 | 10.71 |
| $Na_2O$ | 2.14 | 2.14 | 1.87 | 1.89 | 2.08 | 1.89 | 2.14 |
| $K_2O$ | 0.84 | 0.98 | 1.07 | 1.02 | 1.06 | 0.95 | 0.81 |
| $P_2O_5$ | 0.09 | 0.10 | 0.10 | 0.09 | 0.12 | 0.09 | 0.09 |
| S | 0.07 | 0.05 | 0.05 | 0.05 | 0.02 | 0.05 | 0.06 |
| $H_2O+$ | 0.93 | 1.35 | 1.29 | 1.10 | 1.41 | 0.89 | 0.85 |
| $H_2O-$ | 0.58 | 0.49 | 0.38 | 0.44 | 0.41 | 0.49 | 0.28 |
| $CO_2$ | 0.22 | 0.14 | 0.17 | 0.14 | 0.09 | 0.16 | 0.17 |
| rest | 0.15 | 0.15 | 0.15 | 0.16 | 0.15 | 0.15 | 0.14 |
| | 100.71 | 100.78 | 100.38 | 100.31 | 100.66 | 101.06 | 100.42 |
| O=S | 0.03 | 0.02 | 0.02 | 0.02 | | 0.02 | 0.03 |
| Total | 100.68 | 100.76 | 100.36 | 100.29 | 100.66 | 101.04 | 100.39 |
| | | | | | | | |
| Ba | 225 | 195 | 200 | 305 | 235 | 215 | 185 |
| Rb | 29.1 | 33.2 | 44.0 | 33.7 | 38.5 | 36.0 | 27.5 |
| Sr | 124.4 | 178.6 | 166 | 155.5 | 132 | 128 | 118 |
| Pb | 5 | 5 | 6 | 6 | 7 | 6 | 5 |
| La | 11 | 11 | 12 | 11 | 15 | 11 | 12 |
| Ce | 24 | 25 | 27 | 22 | 31 | 25 | 24 |
| Y | 20.4 | 20.8 | 21 | 20.5 | 26 | 20 | 19 |
| Th | 4.0 | 3.0 | 4.0 | 4.0 | 5.0 | 5.0 | 3.0 |
| U | 1.0 | 2.0 | 1.0 | 1.0 | 4.0 | 1.0 | 1.0 |
| Zr | 95 | 100 | 101 | 95 | 126 | 95 | 91 |
| Nb | 5.0 | 4.5 | 4.5 | 5.0 | 6.0 | 4.5 | 5.0 |
| V | 222 | 238 | 229 | 225 | 239 | 215 | 221 |
| Cr | 110 | 82 | 78 | 114 | 15 | 106 | 124 |
| Mn | 1410 | 1390 | 1350 | 1320 | 1460 | 1300 | 1300 |
| Ni | 78 | 71 | 69 | 80 | 50 | 79 | 79 |
| Cu | 74 | 73 | 74 | 77 | 110 | 81 | 73 |
| Zn | 79 | 81 | 82 | 79 | 90 | 74 | 74 |
| Ga | 15.5 | 17.0 | 16.0 | 17.0 | 18.5 | 16.5 | 15.0 |

| | **84 115** | **84 116** | **84 117** | **84 118** | **84 119** | **84 120** | **84 121** |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 53.94 | 53.49 | 53.12 | 53.70 | 54.50 | 52.92 | 52.33 |
| $TiO_2$ | 0.62 | 0.49 | 0.49 | 0.62 | 0.64 | 0.47 | 0.41 |
| $Al_2O_3$ | 14.45 | 12.65 | 15.34 | 14.60 | 14.85 | 13.59 | 14.03 |
| $Fe_2O_3$ | 1.36 | 1.53 | 1.81 | 1.84 | 1.44 | 1.98 | 1.98 |
| FeO | 7.49 | 7.43 | 5.68 | 7.01 | 7.46 | 6.57 | 5.90 |
| MnO | 0.17 | 0.18 | 0.15 | 0.17 | 0.16 | 0.18 | 0.17 |
| MgO | 6.76 | 9.03 | 7.96 | 6.71 | 6.23 | 8.85 | 9.20 |
| CaO | 10.30 | 11.88 | 11.95 | 10.20 | 10.73 | 12.14 | 12.49 |
| $Na_2O$ | 2.14 | 1.38 | 1.41 | 2.19 | 2.01 | 1.36 | 1.33 |
| $K_2O$ | 0.93 | 0.62 | 0.66 | 0.98 | 0.91 | 0.57 | 0.49 |
| $P_2O_5$ | 0.09 | 0.07 | 0.07 | 0.09 | 0.08 | 0.07 | 0.06 |
| S | 0.09 | 0.02 | 0.02 | 0.03 | 0.02 | 0.04 | 0.02 |
| $H_2O+$ | 0.86 | 0.84 | 0.45 | 0.78 | 0.86 | 1.01 | 0.99 |
| $H_2O-$ | 0.36 | 0.22 | 0.24 | 0.63 | 0.51 | 0.25 | 0.21 |
| $CO_2$ | 0.20 | 0.07 | | 0.11 | 0.11 | 0.10 | 0.12 |
| rest | 0.15 | 0.13 | 0.14 | 0.15 | 0.13 | 0.13 | 0.13 |
| | 99.91 | 100.03 | 99.49 | 99.81 | 100.64 | 100.23 | 99.86 |
| O=S | 0.04 | | | 0.01 | 0.01 | 0.02 | |
| Total | 99.87 | 100.03 | 99.49 | 99.80 | 100.63 | 100.21 | 99.86 |
| | | | | | | | |
| Ba | 200 | 155 | 150 | 215 | 205 | 140 | 125 |
| Rb | 35.2 | 23.0 | 24.0 | 37.0 | 33.0 | 20.0 | 18.0 |
| Sr | 142.0 | 107 | 118 | 155 | 118 | 98 | 105 |
| Pb | 6 | 5 | 4 | 6 | 5 | 6 | 3 |
| La | 11 | 8 | 8 | 11 | 11 | 9 | 6 |
| Ce | 24 | 19 | 20 | 24 | 25 | 17 | 13 |
| Y | 20.2 | 16 | 15 | 20 | 20 | 15 | 13 |
| Th | 3.0 | 1.0 | 2.0 | 4.0 | 3.0 | 2.0 | 3.0 |
| U | 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Zr | 94 | 69 | 71 | 93 | 96 | 64 | 55 |
| Nb | 4.5 | 3.5 | 3.5 | 4.5 | 4.5 | 2.5 | 2.0 |
| V | 222 | 242 | 205 | 214 | 222 | 237 | 226 |
| Cr | 114 | 78 | 199 | 115 | 27 | 99 | 124 |
| Mn | 1300 | 1390 | 1200 | 1300 | 1240 | 1390 | 1310 |
| Ni | 79 | 99 | 100 | 77 | 69 | 102 | 110 |
| Cu | 74 | 51 | 48 | 73 | 79 | 50 | 45 |
| Zn | 77 | 66 | 60 | 76 | 70 | 66 | 60 |
| Ga | 16.5 | 14.5 | 14.5 | 16.0 | 16.5 | 14.0 | 13.5 |

| | **84 122** | **84 123** | **84 124** | **84 125** | **84 126** | **84 127** | **84 128** |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 53.80 | 52.55 | 55.92 | 54.62 | 55.29 | 54.19 | 54.21 |
| $TiO_2$ | 0.56 | 0.36 | 1.04 | 1.50 | 0.82 | 0.75 | 0.64 |
| $Al_2O_3$ | 14.72 | 18.16 | 15.61 | 13.96 | 17.15 | 17.64 | 14.66 |
| $Fe_2O_3$ | 0.97 | 1.49 | 2.72 | 3.97 | 1.68 | 1.52 | 0.76 |
| FeO | 7.26 | 5.04 | 7.96 | 9.02 | 7.48 | 7.24 | 8.02 |
| MnO | 0.16 | 0.14 | 0.15 | 0.18 | 0.13 | 0.14 | 0.17 |
| MgO | 7.81 | 7.24 | 2.38 | 2.89 | 2.52 | 3.10 | 6.75 |
| CaO | 10.81 | 13.16 | 8.56 | 8.31 | 9.42 | 10.25 | 10.99 |
| $Na_2O$ | 2.35 | 1.55 | 2.68 | 2.45 | 2.35 | 2.29 | 1.74 |
| $K_2O$ | 0.68 | 0.51 | 1.33 | 1.30 | 1.21 | 1.05 | 0.68 |
| $P_2O_5$ | 0.08 | 0.05 | 0.14 | 0.15 | 0.13 | 0.11 | 0.09 |
| S | 0.02 | 0.03 | 0.03 | 0.03 | 0.06 | 0.03 | 0.04 |
| $H_2O+$ | 0.82 | 0.64 | 1.23 | 1.17 | 1.29 | 1.62 | 1.13 |
| $H_2O-$ | 0.35 | 0.18 | 0.33 | 0.14 | 0.26 | 0.26 | 0.22 |
| $CO_2$ | 0.15 | 0.07 | 0.15 | 0.10 | 0.19 | 0.12 | 0.16 |
| rest | 0.15 | 0.11 | 0.16 | 0.18 | 0.14 | 0.14 | 0.15 |
| | 100.69 | 101.28 | 100.39 | 99.97 | 100.12 | 100.45 | 100.41 |
| O=S | 0.01 | 0.01 | 0.01 | 0.01 | 0.03 | 0.01 | 0.02 |
| Total | 100.68 | 101.27 | 100.38 | 99.96 | 100.09 | 100.44 | 100.39 |
| | | | | | | | |
| Ba | 175 | 115 | 315 | 305 | 285 | 260 | 190 |
| Rb | 22.0 | 18.0 | 49.5 | 49.0 | 43.5 | 38.0 | 25.4 |
| Sr | 130 | 129 | 145 | 145 | 179 | 189 | 121.2 |
| Pb | 5 | 4 | 9 | 8 | 7 | 7 | 6 |
| La | 10 | 6 | 17 | 18 | 17 | 14 | 12 |
| Ce | 23 | 14 | 40 | 41 | 37 | 34 | 25 |
| Y | 17 | 12 | 28 | 29 | 25 | 22 | 20.1 |
| Th | 4.0 | 1.0 | 7.0 | 6.0 | 6.0 | 3.0 | 3.0 |
| U | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 3.0 | 3.0 |
| Zr | 82 | 48 | 144 | 140 | 124 | 108 | 94 |
| Nb | 4.0 | 2.0 | 7.0 | 8.0 | 6.0 | 4.5 | 4.5 |
| V | 210 | 175 | 214 | 324 | 161 | 176 | 219 |
| Cr | 181 | 104 | 1 | 1 | 1 | 1 | 116 |
| Mn | 1250 | 1090 | 1190 | 1380 | 1040 | 1050 | 1340 |
| Ni | 94 | 87 | 14 | 18 | 19 | 27 | 79 |
| Cu | 63 | 41 | 126 | 147 | 119 | 109 | 80 |
| Zn | 68 | 51 | 92 | 106 | 78 | 75 | 79 |
| Ga | 15.0 | 15.5 | 20.5 | 19.5 | 20.5 | 19.5 | 16.0 |

| | **84 129** | **84 130** | **84 131** | **84 132** | **84 133** | **84 134** | **84 135** |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 54.15 | 53.70 | 55.59 | 54.63 | 55.10 | 56.78 | 63.96 |
| $TiO_2$ | 0.61 | 0.54 | 0.90 | 0.94 | 1.57 | 1.59 | 1.22 |
| $Al_2O_3$ | 14.66 | 15.08 | 16.73 | 16.99 | 14.83 | 14.39 | 11.16 |
| $Fe_2O_3$ | 0.57 | 1.32 | 1.84 | 1.99 | 3.52 | 4.17 | 6.45 |
| FeO | 8.16 | 7.25 | 7.83 | 7.93 | 8.77 | 7.91 | 4.82 |
| MnO | 0.17 | 0.16 | 0.15 | 0.14 | 0.16 | 0.15 | 0.16 |
| MgO | 6.61 | 6.97 | 2.37 | 2.52 | 2.09 | 1.43 | 0.52 |
| CaO | 10.97 | 11.47 | 9.22 | 9.45 | 7.95 | 7.14 | 3.99 |
| $Na_2O$ | 1.88 | 1.67 | 2.69 | 2.45 | 2.69 | 2.72 | 2.76 |
| $K_2O$ | 0.75 | 0.69 | 1.21 | 1.13 | 1.40 | 1.65 | 2.88 |
| $P_2O_5$ | 0.09 | 0.08 | 0.13 | 0.12 | 0.15 | 0.18 | 0.32 |
| S | 0.04 | 0.05 | 0.07 | 0.05 | 0.07 | 0.05 | 0.03 |
| $H_2O+$ | 0.74 | 0.64 | 1.17 | 1.18 | 1.20 | 1.43 | 1.18 |
| $H_2O-$ | 0.25 | 0.31 | 0.28 | 0.22 | 0.34 | 0.38 | 0.76 |
| $CO_2$ | 0.13 | 0.17 | 0.18 | 0.17 | 0.16 | 0.16 | 0.16 |
| rest | 0.14 | 0.13 | 0.15 | 0.15 | 0.19 | 0.16 | 0.18 |
| | 99.92 | 100.23 | 100.51 | 100.06 | 100.19 | 100.29 | 100.55 |
| O=S | 0.02 | 0.02 | 0.03 | 0.02 | 0.03 | 0.02 | 0.01 |
| Total | 99.90 | 100.21 | 100.48 | 100.04 | 100.16 | 100.27 | 100.54 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Ba | 180 | 175 | 285 | 265 | 325 | 380 | 590 |
| Rb | 26.4 | 24.5 | 43.0 | 39.0 | 52.0 | 60.0 | 108.0 |
| Sr | 122.1 | 126 | 149 | 152 | 146 | 134 | 112 |
| Pb | 5 | 6 | 7 | 7 | 9 | 11 | 16 |
| La | 11 | 11 | 15 | 16 | 19 | 24 | 36 |
| Ce | 24 | 21 | 36 | 33 | 47 | 54 | 85 |
| Y | 19.8 | 17 | 25 | 23 | 31 | 37 | 54 |
| Th | 4.0 | 4.0 | 6.0 | 6.0 | 9.0 | 6.0 | 12.0 |
| U | 1.0 | 1.0 | 3.0 | 2.0 | 2.0 | 2.0 | 6.0 |
| Zr | 94 | 79 | 125 | 115 | 152 | 176 | 297 |
| Nb | 4.5 | 4.0 | 6.5 | 6.0 | 7.0 | 8.0 | 14.0 |
| V | 212 | 211 | 193 | 220 | 336 | 149 | 1 |
| Cr | 113 | 96 | 1 | 1 | 1 | 1 | 1 |
| Mn | 1310 | 1270 | 1130 | 1100 | 1240 | 1180 | 1210 |
| Ni | 78 | 80 | 17 | 16 | 11 | 3 | 2 |
| Cu | 64 | 67 | 124 | 135 | 157 | 103 | 26 |
| Zn | 78 | 71 | 86 | 81 | 97 | 102 | 118 |
| Ga | 16.5 | 16.0 | 20.0 | 21.0 | 21.0 | 21.5 | 19.0 |

| | **84 136** | **84 137** | **84 138** | **84 139** | **84 140** | **84 141** | **84 142** |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 62.21 | 55.17 | 54.61 | 64.90 | 53.83 | 54.41 | 69.55 |
| $TiO_2$ | 0.98 | 0.85 | 0.64 | 0.54 | 0.63 | 0.63 | 0.73 |
| $Al_2O_3$ | 13.24 | 16.01 | 14.86 | 10.52 | 14.57 | 14.70 | 19.05 |
| $Fe_2O_3$ | 2.98 | 2.04 | 0.42 | 0.12 | 1.12 | 1.20 | 0.77 |
| FeO | 6.66 | 7.64 | 8.42 | 2.86 | 7.71 | 7.71 | 3.94 |
| MnO | 0.14 | 0.15 | 0.17 | 0.02 | 0.17 | 0.17 | 0.04 |
| MgO | 0.58 | 3.59 | 6.66 | 1.12 | 6.65 | 6.84 | 0.71 |
| CaO | 5.41 | 9.66 | 10.91 | 13.12 | 10.74 | 10.79 | 0.92 |
| $Na_2O$ | 3.05 | 2.31 | 1.87 | 2.37 | 1.78 | 1.95 | 1.14 |
| $K_2O$ | 2.37 | 1.16 | 0.86 | 2.10 | 0.82 | 0.83 | 1.14 |
| $P_2O_5$ | 0.29 | 0.12 | 0.09 | 0.05 | 0.09 | 0.09 | 0.03 |
| S | 0.06 | 0.06 | 0.05 | 0.30 | 0.05 | 0.04 | 0.02 |
| $H_2O+$ | 1.61 | 1.08 | 0.43 | 0.95 | 0.71 | 0.76 | 1.17 |
| $H_2O-$ | 0.43 | 0.07 | 0.23 | 0.17 | 0.52 | 0.29 | 0.25 |
| $CO_2$ | 0.16 | 0.18 | 0.15 | 1.81 | 0.15 | 0.21 | 0.02 |
| rest | 0.16 | 0.14 | 0.15 | 0.14 | 0.14 | 0.15 | 0.17 |
| | 100.33 | 100.23 | 100.52 | 101.09 | 99.68 | 100.77 | 99.65 |
| O=S | 0.03 | 0.03 | 0.02 | | 0.02 | 0.02 | |
| Total | 100.30 | 100.20 | 100.50 | 101.09 | 99.66 | 100.75 | 99.65 |
| | | | | | | | |
| Ba | 510 | 270 | 190 | 210 | 195 | 310 | 545 |
| Rb | 90.0 | 42.5 | 31.7 | 74.0 | 29.8 | 30.0 | 65.0 |
| Sr | 116 | 137 | 123.9 | 366 | 125.8 | 115.8 | 132 |
| Pb | 14 | 8 | 6 | 5 | 5 | 6 | 32 |
| La | 31 | 16 | 10 | 19 | 11 | 12 | 18 |
| Ce | 70 | 38 | 25 | 43 | 24 | 26 | 44 |
| Y | 45 | 24 | 20 | 23 | 19 | 19 | 25 |
| Th | 12.0 | 6.0 | 5.0 | 9.0 | 5.0 | 3.0 | 15.0 |
| U | 4.0 | 1.0 | 1.0 | 1.0 | 2.0 | 1.0 | 4.0 |
| Zr | 245 | 125 | 95 | 158 | 94 | 93 | 284 |
| Nb | 12.5 | 6.0 | 4.0 | 5.5 | 4.5 | 4.0 | 10.5 |
| V | 12 | 187 | 223 | 69 | 214 | 214 | 51 |
| Cr | 1 | 3 | 115 | 27 | 107 | 107 | 20 |
| Mn | 1050 | 1160 | 1330 | 150 | 1290 | 1290 | 280 |
| Ni | 2 | 31 | 80 | 24 | 78 | 75 | 11 |
| Cu | 43 | 106 | 76 | 8 | 76 | 72 | 7 |
| Zn | 103 | 80 | 78 | 97 | 80 | 75 | 110 |
| Ga | 20.0 | 19.5 | 16.5 | 13.5 | 16.5 | 16.5 | 23.5 |

| | **84 143** | **84 144** | **84 145** | **84 146** | **84 147** | **84 148** | **84 149** |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 54.81 | 54.08 | 54.29 | 58.06 | 54.22 | 54.65 | 53.79 |
| $TiO_2$ | 0.66 | 0.63 | 0.64 | 0.40 | 0.63 | 0.64 | 0.63 |
| $Al_2O_3$ | 14.45 | 14.66 | 14.74 | 8.91 | 14.65 | 14.86 | 14.61 |
| $Fe_2O_3$ | 1.53 | 0.97 | 0.96 | 0.09 | 0.71 | 0.32 | 0.65 |
| FeO | 7.70 | 7.92 | 8.02 | 2.30 | 8.13 | 8.52 | 8.15 |
| MnO | 0.18 | 0.17 | 0.17 | 0.15 | 0.17 | 0.17 | 0.18 |
| MgO | 6.34 | 6.78 | 6.58 | 1.11 | 6.64 | 6.77 | 6.64 |
| CaO | 9.73 | 10.84 | 10.76 | 23.87 | 10.87 | 10.95 | 10.93 |
| $Na_2O$ | 2.05 | 2.11 | 2.02 | 2.10 | 1.86 | 1.81 | 1.76 |
| $K_2O$ | 0.98 | 0.84 | 0.96 | 1.50 | 0.81 | 0.85 | 0.83 |
| $P_2O_5$ | 0.10 | 0.09 | 0.09 | 0.09 | 0.09 | 0.10 | 0.09 |
| S | 0.03 | 0.04 | 0.05 | 0.28 | 0.05 | 0.11 | 0.05 |
| $H_2O+$ | 0.92 | 0.54 | 0.67 | 0.97 | 0.44 | 0.39 | 0.61 |
| $H_2O-$ | 0.43 | 0.35 | 0.25 | 0.17 | 0.29 | 0.23 | 0.35 |
| $CO_2$ | 0.14 | 0.18 | 0.19 | 1.10 | 0.16 | 0.29 | 0.19 |
| rest | 0.15 | 0.14 | 0.15 | 0.12 | 0.14 | 0.15 | 0.15 |
| | 100.20 | 100.34 | 100.54 | 101.22 | 99.86 | 100.81 | 99.61 |
| O=S | 0.01 | 0.02 | 0.02 | 0.14 | 0.02 | 0.05 | 0.02 |
| Total | 100.19 | 100.32 | 100.52 | 101.08 | 99.84 | 100.76 | 99.59 |
| | | | | | | | |
| Ba | 235 | 200 | 210 | 215 | 190 | 200 | 190 |
| Rb | 35.6 | 34.6 | 39.0 | 45.0 | 30.5 | 30.2 | 30.4 |
| Sr | 123.8 | 119.3 | 128 | 373 | 120.3 | 123.7 | 128.6 |
| Pb | 6 | 6 | 6 | 8 | 5 | 6 | 5 |
| La | 11 | 12 | 11 | 15 | 11 | 12 | 11 |
| Ce | 27 | 23 | 23 | 36 | 25 | 24 | 26 |
| Y | 21.6 | 20.1 | 20 | 27 | 19.9 | 20.2 | 20.9 |
| Th | 4.0 | 5.0 | 4.0 | 7.0 | 3.0 | 4.0 | 4.0 |
| U | 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 2.0 |
| Zr | 102 | 91 | 93 | 153 | 93 | 95 | 94 |
| Nb | 5.5 | 4.5 | 3.5 | 3.5 | 4.5 | 4.5 | 4.0 |
| V | 232 | 220 | 222 | 44 | 220 | 224 | 223 |
| Cr | 78 | 115 | 100 | 11 | 113 | 117 | 117 |
| Mn | 1390 | 1320 | 1310 | 1150 | 1330 | 1340 | 1370 |
| Ni | 71 | 79 | 75 | 14 | 79 | 80 | 79 |
| Cu | 80 | 62 | 78 | 4 | 65 | 77 | 65 |
| Zn | 85 | 76 | 77 | 63 | 77 | 77 | 79 |
| Ga | 17.5 | 15.0 | 16.0 | 11.5 | 16.0 | 17.0 | 16.5 |

| | **84 150** | **84 151** | **84 152** | **84 153** | **84 154** | **84 155** | **84 156** |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 54.17 | 68.10 | 54.30 | 54.06 | 54.11 | 53.70 | 53.75 |
| $TiO_2$ | 0.63 | 0.46 | 0.64 | 0.62 | 0.62 | 0.58 | 0.51 |
| $Al_2O_3$ | 14.63 | 10.55 | 14.62 | 14.52 | 14.56 | 14.56 | 14.78 |
| $Fe_2O_3$ | 0.95 | 0.34 | 1.65 | 1.25 | 1.39 | 1.28 | 0.98 |
| FeO | 7.90 | 2.95 | 7.29 | 7.62 | 7.44 | 7.26 | 7.17 |
| MnO | 0.17 | 0.02 | 0.17 | 0.17 | 0.17 | 0.16 | 0.16 |
| MgO | 6.75 | 1.39 | 6.60 | 6.68 | 6.82 | 7.25 | 8.08 |
| CaO | 10.92 | 9.26 | 10.92 | 10.64 | 10.94 | 11.15 | 11.65 |
| $Na_2O$ | 1.85 | 2.04 | 1.68 | 1.77 | 1.74 | 1.59 | 1.69 |
| $K_2O$ | 0.84 | 2.42 | 0.85 | 0.92 | 0.83 | 0.76 | 0.67 |
| $P_2O_5$ | 0.09 | 0.10 | 0.09 | 0.09 | 0.09 | 0.08 | 0.07 |
| S | 0.05 | 0.72 | 0.05 | 0.05 | 0.04 | 0.04 | 0.04 |
| $H_2O+$ | 0.67 | 1.51 | 0.78 | 0.75 | 0.66 | 0.58 | 0.57 |
| $H_2O-$ | 0.38 | 0.31 | 0.32 | 0.31 | 0.27 | 0.25 | 0.33 |
| $CO_2$ | 0.21 | 1.67 | 0.12 | 0.13 | 0.11 | 0.14 | 0.09 |
| rest | 0.15 | 0.17 | 0.15 | 0.15 | 0.14 | 0.14 | 0.14 |
| | 100.36 | 102.01 | 100.23 | 99.73 | 99.93 | 99.52 | 100.68 |
| O=S | 0.02 | 0.36 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| Total | 100.34 | 101.65 | 100.21 | 99.71 | 99.91 | 99.50 | 100.66 |
| | | | | | | | |
| Ba | 190 | 325 | 250 | 265 | 195 | 185 | 165 |
| Rb | 29.7 | 76.0 | 29.9 | 33.5 | 29.5 | 27.5 | 24.0 |
| Sr | 128.5 | 500 | 123.6 | 137 | 118 | 116 | 110 |
| Pb | 6 | 17 | 5 | 5 | 5 | 5 | 4 |
| La | 12 | 15 | 11 | 11 | 11 | 11 | 9 |
| Ce | 24 | 32 | 26 | 27 | 25 | 21 | 22 |
| Y | 19.9 | 20 | 20.7 | 19 | 19 | 18 | 16 |
| Th | 4.0 | 7.0 | 4.0 | 5.0 | 3.0 | 5.0 | 3.0 |
| U | 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 2.0 |
| Zr | 92 | 142 | 95 | 92 | 90 | 82 | 72 |
| Nb | 5.0 | 5.0 | 4.5 | 4.5 | 4.0 | 4.0 | 3.0 |
| V | 223 | 70 | 218 | 209 | 217 | 205 | 207 |
| Cr | 115 | 27 | 111 | 111 | 121 | 144 | 195 |
| Mn | 1330 | 120 | 1310 | 1280 | 1280 | 1230 | 1250 |
| Ni | 79 | 25 | 76 | 77 | 82 | 83 | 95 |
| Cu | 71 | 10 | 75 | 72 | 72 | 67 | 60 |
| Zn | 77 | 89 | 76 | 74 | 75 | 70 | 65 |
| Ga | 16.0 | 13.5 | 16.5 | 16.0 | 16.5 | 16.0 | 15.0 |

| | **84 157** | **84 158** | **84 159** | **84 160** | **84 161** | **84 162** | **84 163** |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 53.52 | 53.73 | 53.34 | 53.32 | 54.93 | 54.93 | 55.97 |
| $TiO_2$ | 0.49 | 0.50 | 0.56 | 0.69 | 0.71 | 0.99 | 0.98 |
| $Al_2O_3$ | 13.78 | 13.95 | 15.12 | 17.56 | 15.03 | 16.98 | 16.02 |
| $Fe_2O_3$ | 0.93 | 1.26 | 1.16 | 1.49 | 1.74 | 2.04 | 2.20 |
| FeO | 7.58 | 7.12 | 7.27 | 7.00 | 8.56 | 7.52 | 7.93 |
| MnO | 0.17 | 0.17 | 0.16 | 0.15 | 0.18 | 0.14 | 0.15 |
| MgO | 9.08 | 8.75 | 6.78 | 4.08 | 4.32 | 2.18 | 2.31 |
| CaO | 11.56 | 11.64 | 11.50 | 11.20 | 9.83 | 9.09 | 8.70 |
| $Na_2O$ | 1.44 | 1.38 | 1.61 | 1.98 | 2.13 | 2.55 | 2.58 |
| $K_2O$ | 0.63 | 0.67 | 0.74 | 0.85 | 1.06 | 1.28 | 1.37 |
| $P_2O_5$ | 0.07 | 0.09 | 0.08 | 0.10 | 0.12 | 0.13 | 0.15 |
| S | 0.04 | 0.04 | 0.04 | 0.06 | 0.08 | 0.08 | 0.08 |
| $H_2O+$ | 0.55 | 0.67 | 0.80 | 0.88 | 1.10 | 1.33 | 1.42 |
| $H_2O-$ | 0.30 | 0.29 | 0.33 | 0.29 | 0.42 | 0.28 | 0.41 |
| $CO_2$ | 0.13 | 0.19 | 0.11 | 0.48 | 0.15 | 0.19 | 0.20 |
| rest | 0.15 | 0.15 | 0.13 | 0.12 | 0.15 | 0.15 | 0.15 |
| | 100.42 | 100.60 | 99.73 | 100.25 | 100.51 | 99.86 | 100.62 |
| O=S | 0.02 | 0.02 | 0.02 | 0.03 | 0.04 | 0.04 | 0.04 |
| Total | 100.40 | 100.58 | 99.71 | 100.22 | 100.47 | 99.82 | 100.58 |
| | | | | | | | |
| Ba | 150 | 160 | 175 | 200 | 250 | 290 | 305 |
| Rb | 23.0 | 23.5 | 27.0 | 30.5 | 39.0 | 48.5 | 51.0 |
| Sr | 105 | 106 | 118 | 141 | 130 | 158 | 147 |
| Pb | 3 | 5 | 6 | 6 | 6 | 8 | 9 |
| La | 9 | 9 | 11 | 12 | 15 | 17 | 18 |
| Ce | 19 | 16 | 22 | 29 | 30 | 36 | 43 |
| Y | 15 | 17 | 17 | 19 | 24 | 26 | 29 |
| Th | 2.0 | 5.0 | 5.0 | 4.0 | 7.0 | 6.0 | 7.0 |
| U | 3.0 | 2.0 | 1.0 | 3.0 | 1.0 | 2.0 | 1.0 |
| Zr | 67 | 71 | 82 | 96 | 118 | 137 | 149 |
| Nb | 3.5 | 3.5 | 4.0 | 5.0 | 5.0 | 6.0 | 7.0 |
| V | 222 | 223 | 209 | 191 | 215 | 209 | 192 |
| Cr | 244 | 218 | 90 | 6 | 1 | 1 | 1 |
| Mn | 1320 | 1300 | 1250 | 1140 | 1360 | 1120 | 1180 |
| Ni | 114 | 109 | 79 | 41 | 38 | 16 | 16 |
| Cu | 62 | 59 | 69 | 85 | 144 | 118 | 120 |
| Zn | 70 | 67 | 69 | 70 | 91 | 88 | 94 |
| Ga | 14.0 | 15.0 | 17.0 | 18.5 | 18.5 | 19.5 | 20.5 |

| | **84 164** | **84 165** | **84 166** | **84 167** | **84 167b** | **84 168** | **84 169** |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 56.00 | 55.79 | 57.67 | 54.19 | 54.19 | 51.04 | 53.70 |
| $TiO_2$ | 0.89 | 1.02 | 0.90 | 0.63 | 0.64 | 0.64 | 0.62 |
| $Al_2O_3$ | 16.74 | 15.81 | 16.48 | 14.74 | 14.67 | 15.06 | 14.50 |
| $Fe_2O_3$ | 2.07 | 1.99 | 1.48 | 0.61 | 0.75 | 2.70 | 1.80 |
| FeO | 7.44 | 8.32 | 7.88 | 8.30 | 8.12 | 5.36 | 7.01 |
| MnO | 0.14 | 0.15 | 0.13 | 0.18 | 0.17 | 0.27 | 0.18 |
| MgO | 2.11 | 2.17 | 1.57 | 6.68 | 6.62 | 5.29 | 6.88 |
| CaO | 8.89 | 8.84 | 7.94 | 10.89 | 10.92 | 12.15 | 9.94 |
| $Na_2O$ | 2.60 | 2.46 | 2.85 | 1.94 | 1.83 | 1.74 | 2.01 |
| $K_2O$ | 1.32 | 1.37 | 1.61 | 0.66 | 0.75 | 0.81 | 1.01 |
| $P_2O_5$ | 0.14 | 0.15 | 0.17 | 0.09 | 0.09 | 0.10 | 0.09 |
| S | 0.07 | 0.08 | 0.08 | 0.04 | 0.04 | 0.05 | 0.05 |
| $H_2O+$ | 1.44 | 1.44 | 1.65 | 0.57 | 0.45 | 1.75 | 1.53 |
| $H_2O-$ | 0.32 | 0.28 | 0.22 | 0.24 | 0.29 | 1.25 | 0.49 |
| $CO_2$ | 0.16 | 0.16 | 0.22 | 0.20 | 0.11 | 2.31 | 0.29 |
| rest | 0.15 | 0.15 | 0.15 | 0.14 | 0.14 | 0.18 | 0.21 |
| | 100.48 | 100.18 | 101.00 | 100.10 | 99.78 | 100.70 | 100.31 |
| O=S | 0.03 | 0.04 | 0.04 | 0.02 | 0.02 | 0.02 | 0.02 |
| Total | 100.45 | 100.14 | 100.96 | 100.08 | 99.76 | 100.68 | 100.29 |
| | | | | | | | |
| Ba | 305 | 310 | 345 | 190 | 190 | 460 | 785 |
| Rb | 48.5 | 50.0 | 60.0 | 28.0 | 32.5 | 29.3 | 38.8 |
| Sr | 149 | 141 | 151 | 115.7 | 115.1 | 146.4 | 137.7 |
| Pb | 9 | 8 | 9 | 6 | 5 | 5 | 5 |
| La | 17 | 18 | 20 | 11 | 11 | 12 | 11 |
| Ce | 39 | 43 | 4.7 | 27 | 24 | 26 | 26 |
| Y | 28 | 29 | 30 | 20.2 | 19.8 | 21.6 | 19.6 |
| Th | 5.0 | 5.0 | 6.0 | 3.0 | 3.0 | 5.0 | 4.0 |
| U | 1.0 | 2.0 | 2.0 | 1.0 | 1.0 | 2.0 | 1.0 |
| Zr | 146 | 150 | 168 | 93 | 93 | 95 | 90 |
| Nb | 7.0 | 7.0 | 7.5 | 5.0 | 4.0 | 4.5 | 4.5 |
| V | 177 | 183 | 132 | 227 | 221 | 239 | 226 |
| Cr | 1 | 1 | 1 | 116 | 114 | 122 | 117 |
| Mn | 1120 | 1170 | 1000 | 1380 | 1340 | 2110 | 1420 |
| Ni | 13 | 14 | 8 | 80 | 78 | 82 | 79 |
| Cu | 116 | 121 | 86 | 64 | 70 | 74 | 72 |
| Zn | 89 | 93 | 81 | 80 | 77 | 81 | 77 |
| Ga | 20.0 | 19.5 | 20.5 | 15.5 | 16.5 | 16.0 | 15.0 |

| | **84 170** | **84 171** | **84 172** | **84 173** | **84 174** | **84 175** | **84 176** |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 53.91 | 54.01 | 53.99 | 53.98 | 54.17 | 53.56 | 53.53 |
| $TiO_2$ | 0.62 | 0.63 | 0.62 | 0.60 | 0.59 | 0.53 | 0.52 |
| $Al_2O_3$ | 14.57 | 14.57 | 14.54 | 14.40 | 14.29 | 14.19 | 14.39 |
| $Fe_2O_3$ | 1.72 | 1.99 | 1.47 | 1.54 | 1.34 | 1.27 | 1.12 |
| FeO | 7.17 | 6.95 | 7.41 | 7.23 | 7.32 | 7.18 | 7.03 |
| MnO | 0.18 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 |
| MgO | 6.89 | 6.54 | 6.83 | 7.24 | 7.40 | 8.11 | 8.28 |
| CaO | 9.67 | 10.33 | 10.59 | 10.98 | 10.83 | 11.19 | 11.31 |
| $Na_2O$ | 2.20 | 2.10 | 2.02 | 1.73 | 1.80 | 1.67 | 1.53 |
| $K_2O$ | 1.18 | 0.97 | 0.90 | 0.74 | 0.76 | 0.70 | 0.66 |
| $P_2O_5$ | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.08 | 0.07 |
| S | 0.04 | 0.05 | 0.04 | 0.05 | 0.04 | | |
| $H_2O+$ | 1.40 | 1.10 | 0.83 | 1.69 | 0.71 | 0.68 | 0.92 |
| $H_2O-$ | 0.50 | 0.43 | 0.40 | 0.42 | 0.39 | 0.38 | 0.30 |
| $CO_2$ | 0.15 | 0.07 | 0.01 | 0.27 | 0.16 | 0.12 | 0.07 |
| rest | 0.29 | 0.17 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 |
| | 100.58 | 100.17 | 100.06 | 101.28 | 100.21 | 99.98 | 100.05 |
| O=S | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | | |
| Total | 100.56 | 100.15 | 100.04 | 101.26 | 100.19 | 99.98 | 100.05 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Ba | 1400 | 330 | 210 | 180 | 175 | 165 | 150 |
| Rb | 44.5 | 36.5 | 33.0 | 26.0 | 27.0 | 24.5 | 24.0 |
| Sr | 167.8 | 164 | 139 | 111 | 112 | 110 | 107 |
| Pb | 6 | 6 | 5 | 6 | 5 | 5 | 4 |
| La | 12 | 11 | 11 | 11 | 14 | 9 | 9 |
| Ce | 28 | 24 | 24 | 22 | 25 | 19 | 21 |
| Y | 20.0 | 20 | 20 | 19 | 19 | 16 | 16 |
| Th | 5.0 | 6.0 | 5.0 | 5.0 | 3.0 | 3.0 | 4.0 |
| U | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 3.0 |
| Zr | 88 | 94 | 91 | 90 | 86 | 78 | 75 |
| Nb | 4.5 | 4.0 | 4.5 | 4.0 | 4.0 | 3.0 | 3.5 |
| V | 220 | 228 | 225 | 227 | 224 | 223 | 216 |
| Cr | 115 | 110 | 121 | 147 | 166 | 213 | 228 |
| Mn | 1400 | 1320 | 1330 | 1330 | 1350 | 1320 | 1280 |
| Ni | 79 | 78 | 83 | 88 | 92 | 102 | 103 |
| Cu | 76 | 76 | 74 | 70 | 68 | 63 | 58 |
| Zn | 79 | 79 | 77 | 74 | 75 | 71 | 66 |
| Ga | 16.5 | 15.5 | 16.0 | 16.5 | 16.0 | 15.5 | 15.0 |

| | **84 177** | **84 178** | **84 179** | **84 180** | **84 181** | **84 182** | **84 183** |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 53.24 | 53.57 | 53.36 | 53.34 | 53.22 | 52.83 | 53.73 |
| $TiO_2$ | 0.48 | 0.47 | 0.49 | 0.53 | 0.53 | 0.52 | 0.54 |
| $Al_2O_3$ | 14.12 | 13.42 | 14.07 | 14.39 | 15.60 | 15.95 | 12.41 |
| $Fe_2O_3$ | 0.98 | 1.11 | 1.51 | 1.22 | 1.28 | 1.23 | 1.13 |
| FeO | 6.98 | 6.91 | 6.66 | 7.21 | 6.72 | 6.65 | 8.10 |
| MnO | 0.17 | 0.17 | 0.17 | 0.17 | 0.16 | 0.16 | 0.19 |
| MgO | 8.85 | 9.41 | 8.53 | 7.79 | 6.63 | 6.22 | 8.91 |
| CaO | 11.65 | 11.60 | 11.73 | 11.70 | 11.78 | 11.59 | 11.47 |
| $Na_2O$ | 1.37 | 1.59 | 1.44 | 1.60 | 1.69 | 1.71 | 1.45 |
| $K_2O$ | 0.60 | 0.63 | 0.63 | 0.67 | 0.73 | 0.70 | 0.65 |
| $P_2O_5$ | 0.07 | 0.07 | 0.07 | 0.07 | 0.15 | 0.08 | 0.07 |
| S | 0.02 | | | | 0.04 | 0.03 | 0.02 |
| $H_2O+$ | 1.01 | 0.83 | 0.41 | 1.08 | 0.99 | 1.59 | 1.28 |
| $H_2O-$ | 0.30 | 0.85 | 0.39 | 0.30 | 0.33 | 0.36 | 0.31 |
| $CO_2$ | 0.23 | 0.13 | 0.13 | 0.10 | 0.14 | 0.17 | 0.11 |
| rest | 0.15 | 0.16 | 0.15 | 0.14 | 0.13 | 0.13 | 0.14 |
| | 100.22 | 100.92 | 99.74 | 100.31 | 100.12 | 99.92 | 100.51 |
| O=S | 0.01 | | | | 0.02 | 0.01 | 0.01 |
| Total | 100.21 | 100.92 | 99.74 | 100.31 | 100.10 | 99.91 | 100.50 |
| | | | | | | | |
| Ba | 140 | 140 | 150 | 150 | 170 | 160 | 155 |
| Rb | 21.0 | 22.5 | 22.5 | 24.5 | 25.5 | 26.0 | 23.0 |
| Sr | 105 | 100 | 102 | 111 | 118 | 124 | 96 |
| Pb | 4 | 4 | 3 | 4 | 5 | 5 | 4 |
| La | 9 | 7 | 9 | 9 | 10 | 9 | 10 |
| Ce | 16 | 15 | 20 | 21 | 20 | 21 | 19 |
| Y | 15 | 14 | 15 | 16 | 17 | 17 | 17 |
| Th | 2.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 1.0 |
| U | 1.0 | 1.0 | 1.0 | 1.0 | 2.0 | 1.0 | 1.0 |
| Zr | 69 | 67 | 70 | 75 | 80 | 84 | 75 |
| Nb | 3.5 | 3.0 | 3.0 | 3.5 | 4.0 | 3.0 | 3.5 |
| V | 223 | 233 | 226 | 232 | 212 | 208 | 252 |
| Cr | 259 | 288 | 227 | 153 | 98 | 70 | 127 |
| Mn | 1290 | 1320 | 1300 | 1340 | 1250 | 1210 | 1490 |
| Ni | 118 | 126 | 107 | 98 | 82 | 75 | 107 |
| Cu | 52 | 51 | 55 | 61 | 60 | 60 | 67 |
| Zn | 67 | 67 | 67 | 69 | 68 | 67 | 75 |
| Ga | 14.0 | 14.0 | 14.5 | 15.0 | 16.5 | 15.5 | 14.0 |

| | **84 184** | **84 185** | **84 186** | **84 187** | **84 188** | **84 189** | **84 190** |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 53.60 | 53.70 | 53.48 | 53.76 | 53.67 | 54.13 | 54.20 |
| $TiO_2$ | 0.60 | 0.62 | 0.61 | 0.61 | 0.61 | 0.70 | 0.70 |
| $Al_2O_3$ | 15.20 | 15.04 | 16.16 | 13.02 | 14.54 | 15.76 | 16.05 |
| $Fe_2O_3$ | 1.24 | 1.66 | 1.40 | 1.65 | 1.56 | 1.63 | 1.80 |
| FeO | 7.35 | 7.03 | 7.08 | 8.11 | 7.61 | 7.24 | 7.10 |
| MnO | 0.17 | 0.17 | 0.16 | 0.19 | 0.18 | 0.16 | 0.16 |
| MgO | 6.49 | 6.23 | 5.44 | 7.46 | 6.46 | 4.86 | 4.51 |
| CaO | 11.24 | 10.90 | 11.18 | 10.87 | 10.89 | 10.92 | 10.49 |
| $Na_2O$ | 1.80 | 1.94 | 1.86 | 1.77 | 1.90 | 1.97 | 2.03 |
| $K_2O$ | 0.76 | 0.84 | 0.83 | 0.81 | 0.86 | 0.96 | 1.00 |
| $P_2O_5$ | 0.08 | 0.09 | 0.08 | 0.08 | 0.09 | 0.10 | 0.09 |
| S | 0.05 | 0.04 | 0.04 | 0.06 | 0.05 | 0.03 | 0.05 |
| $H_2O+$ | 1.10 | 1.05 | 1.13 | 1.02 | 0.96 | 1.19 | 1.16 |
| $H_2O-$ | 0.29 | 0.30 | 0.42 | 0.35 | 0.41 | 0.46 | 0.46 |
| $CO_2$ | 0.13 | 0.14 | 0.12 | 0.15 | 0.14 | 0.08 | 0.15 |
| rest | 0.13 | 0.14 | 0.13 | 0.14 | 0.14 | 0.13 | 0.13 |
| | 100.23 | 99.89 | 100.12 | 100.05 | 100.07 | 100.32 | 100.08 |
| O=S | 0.02 | 0.02 | 0.02 | 0.03 | 0.02 | 0.01 | 0.02 |
| Total | 100.21 | 99.87 | 100.10 | 100.02 | 100.05 | 100.31 | 100.06 |
| | | | | | | | |
| Ba | 185 | 195 | 190 | 190 | 195 | 210 | 230 |
| Rb | 28.0 | 31.5 | 30.5 | 28.5 | 31.5 | 35.0 | 36.5 |
| Sr | 117 | 121 | 127 | 105 | 120 | 133 | 132 |
| Pb | 5 | 5 | 6 | 5 | 6 | 5 | 6 |
| La | 11 | 11 | 11 | 11 | 11 | 13 | 14 |
| Ce | 22 | 24 | 25 | 22 | 23 | 29 | 28 |
| Y | 18 | 19 | 19 | 19 | 19 | 21 | 21 |
| Th | 3.0 | 2.0 | 2.0 | 4.0 | 4.0 | 5.0 | 6.0 |
| U | 2.0 | 3.0 | 1.0 | 1.0 | 2.0 | 1.0 | 1.0 |
| Zr | 86 | 92 | 93 | 87 | 91 | 104 | 108 |
| Nb | 4.5 | 4.5 | 4.5 | 4.0 | 4.0 | 4.5 | 5.0 |
| V | 219 | 221 | 201 | 243 | 229 | 218 | 202 |
| Cr | 74 | 59 | 39 | 62 | 45 | 17 | 14 |
| Mn | 1300 | 1300 | 1220 | 1470 | 1360 | 1260 | 1230 |
| Ni | 76 | 73 | 59 | 88 | 73 | 51 | 46 |
| Cu | 69 | 73 | 74 | 74 | 77 | 72 | 82 |
| Zn | 72 | 75 | 72 | 80 | 79 | 75 | 78 |
| Ga | 15.5 | 16.5 | 17.0 | 15.0 | 16.5 | 17.5 | 18.0 |

| | **84 191** | **84 192** | **84 193** | **84 194** | **84 195** | **84 196** | **84 197** |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 53.91 | 53.84 | 65.91 | 55.39 | 55.29 | 53.99 | 54.77 |
| $TiO_2$ | 0.73 | 0.67 | 0.85 | 0.76 | 0.75 | 0.64 | 0.64 |
| $Al_2O_3$ | 16.77 | 15.58 | 18.84 | 14.27 | 14.43 | 14.62 | 14.69 |
| $Fe_2O_3$ | 2.10 | 2.03 | 0.19 | 1.64 | 1.04 | 1.71 | 1.15 |
| FeO | 6.87 | 7.46 | 4.88 | 8.21 | 8.32 | 7.10 | 7.76 |
| MnO | 0.15 | 0.17 | 0.06 | 0.17 | 0.19 | 0.17 | 0.17 |
| MgO | 3.92 | 5.10 | 1.51 | 5.09 | 5.47 | 6.68 | 6.50 |
| CaO | 10.47 | 10.56 | 0.85 | 9.10 | 10.08 | 10.20 | 10.71 |
| $Na_2O$ | 2.07 | 1.95 | 1.32 | 2.37 | 2.06 | 2.10 | 1.83 |
| $K_2O$ | 1.00 | 0.95 | 3.34 | 1.23 | 0.77 | 0.93 | 0.80 |
| $P_2O_5$ | 0.11 | 0.10 | 0.20 | 0.11 | 0.12 | 0.09 | 0.10 |
| S | 0.04 | 0.03 | | 0.09 | 0.07 | 0.04 | 0.04 |
| $H_2O+$ | 1.10 | 1.10 | 1.03 | 0.98 | 0.89 | 1.07 | 0.95 |
| $H_2O-$ | 0.35 | 0.40 | 0.22 | 0.50 | 0.35 | 0.52 | 0.34 |
| $CO_2$ | 0.07 | 0.04 | 0.01 | 0.19 | 0.74 | 0.10 | 0.10 |
| rest | 0.13 | 0.13 | 0.20 | 0.16 | 0.15 | 0.16 | 0.15 |
| | 99.79 | 100.11 | 99.41 | 100.26 | 100.72 | 100.12 | 100.70 |
| O=S | 0.02 | 0.01 | | 0.04 | 0.03 | 0.02 | 0.02 |
| Total | 99.77 | 100.10 | 99.41 | 100.22 | 100.69 | 100.10 | 100.68 |
| | | | | | | | |
| Ba | 230 | 230 | 510 | 270 | 255 | 270 | 210 |
| Rb | 36.5 | 35.0 | 151.0 | 44.0 | 35.5 | 36.2 | 29.5 |
| Sr | 140 | 139 | 179 | 197 | 143 | 151.5 | 121 |
| Pb | 6 | 6 | 27 | 7 | 8 | 6 | 6 |
| La | 15 | 12 | 50 | 15 | 15 | 12 | 12 |
| Ce | 31 | 25 | 105 | 33 | 30 | 25 | 25 |
| Y | 22 | 21 | 36 | 25 | 24 | 20.7 | 20 |
| Th | 5.0 | 3.0 | 23.0 | 6.0 | 5.0 | 1.0 | 5.0 |
| U | 2.0 | 2.0 | 4.0 | 1.0 | 2.0 | 1.0 | 1.0 |
| Zr | 110 | 101 | 219 | 124 | 120 | 95 | 95 |
| Nb | 5.5 | 5.0 | 14.5 | 5.5 | 5.5 | 4.0 | 4.0 |
| V | 194 | 213 | 98 | 224 | 231 | 220 | 225 |
| Cr | 6 | 11 | 68 | 39 | 48 | 110 | 101 |
| Mn | 1180 | 1280 | 485 | 1310 | 1500 | 1300 | 1350 |
| Ni | 37 | 49 | 35 | 51 | 54 | 78 | 72 |
| Cu | 91 | 87 | 31 | 87 | 88 | 74 | 73 |
| Zn | 76 | 76 | 111 | 88 | 87 | 81 | 78 |
| Ga | 18.5 | 17.5 | 25.0 | 17.5 | 17.0 | 16.5 | 16.5 |

| | **84 198** | **84 199** | **84 200** | **84 201** | **84 202** | **84 203** | **84 204** |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 55.04 | 54.54 | 54.51 | 54.17 | Not | 54.44 | 53.79 |
| $TiO_2$ | 0.82 | 0.63 | 0.63 | 0.63 | Analysed | 0.63 | 0.62 |
| $Al_2O_3$ | 13.64 | 14.78 | 14.69 | 14.65 | | 14.70 | 14.58 |
| $Fe_2O_3$ | 2.49 | 1.24 | 0.91 | 1.83 | | 0.92 | 2.06 |
| FeO | 8.09 | 7.61 | 8.00 | 7.25 | | 7.96 | 6.82 |
| MnO | 0.17 | 0.18 | 0.17 | 0.18 | | 0.18 | 0.17 |
| MgO | 5.13 | 6.79 | 6.77 | 6.72 | | 6.63 | 6.66 |
| CaO | 9.31 | 10.55 | 10.61 | 10.04 | | 10.83 | 10.90 |
| $Na_2O$ | 2.17 | 2.20 | 1.95 | 2.14 | | 1.68 | 1.61 |
| $K_2O$ | 1.19 | 0.83 | 0.98 | 1.09 | | 0.90 | 0.88 |
| $P_2O_5$ | 0.12 | 0.09 | 0.09 | 0.10 | | 0.09 | 0.09 |
| S | 0.03 | 0.05 | 0.04 | 0.04 | | 0.04 | 0.03 |
| $H_2O+$ | 0.85 | 0.65 | 0.71 | 1.13 | | 0.45 | 0.63 |
| $H_2O-$ | 0.49 | 0.28 | 0.28 | 0.45 | | 0.41 | 0.67 |
| $CO_2$ | 0.06 | 0.13 | 0.13 | 0.10 | | 0.08 | 0.20 |
| rest | 0.15 | 0.15 | 0.15 | 0.17 | | 0.15 | 0.15 |
| | 99.75 | 100.70 | 100.62 | 100.69 | | 100.09 | 99.86 |
| O=S | 0.01 | 0.02 | 0.02 | 0.02 | | 0.02 | 0.01 |
| Total | 99.74 | 100.68 | 100.60 | 100.67 | | 100.07 | 99.85 |
| | | | | | | | |
| Ba | 250 | 210 | 220 | 310 | | 220 | 200 |
| Rb | 45.5 | 31.1 | 37.6 | 39.5 | | 35.4 | 29.0 |
| Sr | 183 | 130.4 | 134.8 | 199 | | 119.5 | 124 |
| Pb | 7 | 5 | 6 | 6 | | 6 | 5 |
| La | 15 | 11 | 11 | 11 | | 12 | 11 |
| Ce | 31 | 24 | 26 | 26 | | 25 | 27 |
| Y | 25 | 20.2 | 20.0 | 20 | | 20.3 | 20 |
| Th | 6.0 | 3.0 | 6.0 | 3.0 | | 2.0 | 5.0 |
| U | 1.0 | 1.0 | 2.0 | 1.0 | | 4.0 | 2.0 |
| Zr | 126 | 94 | 93 | 95 | | 93 | 94 |
| Nb | 6.0 | 4.0 | 4.5 | 4.0 | | 4.0 | 4.5 |
| V | 3203 | 233 | 219 | 219 | | 231 | 224 |
| Cr | 13 | 115 | 109 | 110 | | 114 | 114 |
| Mn | 1340 | 1370 | 1320 | 1360 | | 1380 | 1330 |
| Ni | 46 | 81 | 78 | 78 | | 78 | 79 |
| Cu | 81 | 77 | 76 | 75 | | 78 | 74 |
| Zn | 77 | 79 | 77 | 79 | | 78 | 78 |
| Ga | 17.5 | 16.5 | 16.5 | 16.0 | | 15.5 | 16.5 |

| | **84 205** | **84 206** | **84 207** | **84 208** | **84 209** | **84 210** | **84 211** |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 53.94 | 53.85 | 54.06 | 54.09 | 54.40 | 53.65 | 53.77 |
| $TiO_2$ | 0.64 | 0.63 | 0.63 | 0.64 | 0.65 | 0.64 | 0.65 |
| $Al_2O_3$ | 14.86 | 14.61 | 14.65 | 14.59 | 14.61 | 14.63 | 14.75 |
| $Fe_2O_3$ | 2.08 | 0.82 | 0.69 | 1.05 | 1.18 | 1.36 | 1.38 |
| FeO | 6.66 | 7.94 | 8.07 | 7.77 | 7.82 | 7.68 | 7.57 |
| MnO | 0.17 | 0.18 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 |
| MgO | 6.13 | 6.63 | 6.70 | 6.65 | 6.65 | 6.68 | 6.83 |
| CaO | 10.27 | 10.85 | 11.03 | 10.92 | 10.96 | 10.93 | 10.69 |
| $Na_2O$ | 1.92 | 1.91 | 1.80 | 1.76 | 1.76 | 1.82 | 2.04 |
| $K_2O$ | 0.88 | 0.89 | 0.76 | 0.82 | 0.69 | 0.79 | 1.05 |
| $P_2O_5$ | 0.09 | 0.10 | 0.09 | 0.09 | 0.09 | 0.09 | 0.10 |
| S | 0.03 | 0.05 | 0.04 | 0.05 | 0.03 | 0.02 | 0.02 |
| $H_2O+$ | 1.08 | 1.04 | 0.66 | 0.71 | 0.92 | 0.98 | 1.03 |
| $H_2O-$ | 1.10 | 0.41 | 0.29 | 0.26 | 0.33 | 0.42 | 0.43 |
| $CO_2$ | 0.04 | 0.41 | 0.18 | 0.32 | 0.28 | 0.21 | 0.20 |
| rest | 0.15 | 0.15 | 0.14 | 0.14 | 0.14 | 0.14 | 0.15 |
| | 100.04 | 100.47 | 99.96 | 100.03 | 100.68 | 100.21 | 100.83 |
| O=S | 0.01 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 |
| Total | 100.03 | 100.45 | 99.94 | 100.01 | 100.67 | 100.20 | 100.82 |
| | | | | | | | |
| Ba | 215 | 205 | 180 | 200 | 185 | 190 | 200 |
| Rb | 31.8 | 34.4 | 23.0 | 27.5 | 24.0 | 27.5 | 46.0 |
| Sr | 123.0 | 125.0 | 119 | 119 | 120 | 121 | 117 |
| Pb | 12 | 7 | 6 | 6 | 6 | 5 | 6 |
| La | 11 | 11 | 11 | 11 | 11 | 12 | 11 |
| Ce | 26 | 22 | 26 | 26 | 24 | 25 | 22 |
| Y | 21.1 | 20.1 | 19 | 19 | 20 | 19 | 19 |
| Th | 3.0 | 3.0 | 4.0 | 5.0 | 2.0 | 4.0 | 5.0 |
| U | 1.0 | 2.0 | 1.0 | 2.0 | 2.0 | 1.0 | 2.0 |
| Zr | 96 | 93 | 92 | 94 | 86 | 88 | 85 |
| Nb | 5.0 | 4.5 | 4.0 | 4.0 | 5.0 | 4.0 | 4.5 |
| V | 232 | 224 | 227 | 221 | 224 | 222 | 225 |
| Cr | 108 | 114 | 116 | 110 | 112 | 109 | 110 |
| Mn | 1240 | 1370 | 1320 | 1290 | 1320 | 1300 | 1320 |
| Ni | 83 | 79 | 80 | 75 | 77 | 77 | 79 |
| Cu | 77 | 76 | 76 | 73 | 72 | 77 | 72 |
| Zn | 98 | 81 | 78 | 76 | 78 | 79 | 79 |
| Ga | 17.0 | 16.0 | 16.0 | 16.5 | 15.5 | 17.5 | 16.0 |

| | **84 212** | **84 213** | **84 214** | **84 215** | **84 216** | **84 217** | **84 218** |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 54.01 | 54.86 | 55.05 | 55.04 | 54.69 | 55.18 | 54.65 |
| $TiO_2$ | 0.64 | 0.68 | 0.67 | 0.67 | 0.65 | 0.66 | 0.66 |
| $Al_2O_3$ | 14.84 | 14.60 | 14.49 | 14.48 | 14.48 | 14.68 | 14.51 |
| $Fe_2O_3$ | 1.13 | 0.80 | 0.61 | 0.72 | 1.12 | 1.02 | 1.06 |
| FeO | 7.87 | 8.35 | 8.56 | 8.45 | 8.46 | 8.06 | 8.18 |
| MnO | 0.17 | 0.19 | 0.18 | 0.18 | 0.18 | 0.17 | 0.17 |
| MgO | 6.94 | 6.08 | 6.21 | 6.26 | 6.31 | 6.29 | 6.39 |
| CaO | 11.28 | 10.40 | 10.38 | 10.41 | 10.60 | 10.65 | 10.62 |
| $Na_2O$ | 1.74 | 1.92 | 2.03 | 2.02 | 1.96 | 2.08 | 1.94 |
| $K_2O$ | 0.71 | 0.76 | 1.05 | 0.98 | 0.89 | 0.91 | 0.90 |
| $P_2O_5$ | 0.10 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.10 |
| S | 0.02 | 0.07 | 0.05 | 0.05 | 0.06 | 0.05 | 0.05 |
| $H_2O+$ | 0.84 | 0.99 | 0.55 | 0.57 | 0.48 | 0.61 | 0.58 |
| $H_2O-$ | 0.44 | 0.29 | 0.20 | 0.20 | 0.23 | 0.20 | 0.19 |
| $CO_2$ | 0.10 | 0.11 | 0.07 | 0.06 | 0.03 | 0.11 | 0.17 |
| rest | 0.14 | 0.14 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 |
| | 100.97 | 100.35 | 100.36 | 100.35 | 100.40 | 100.93 | 100.32 |
| O=S | 0.01 | 0.03 | 0.02 | 0.02 | 0.03 | 0.02 | 0.02 |
| Total | 100.96 | 100.32 | 100.34 | 100.33 | 100.37 | 100.91 | 100.30 |
| | | | | | | | |
| Ba | 180 | 175 | 245 | 230 | 210 | 205 | 210 |
| Rb | 22.0 | 27.9 | 40.0 | 35.0 | 30.0 | 30.5 | 31.5 |
| Sr | 117 | 130.8 | 143.8 | 140 | 138 | 139 | 133 |
| Pb | 5 | 6 | 7 | 6 | 6 | 6 | 7 |
| La | 10 | 12 | 12 | 12 | 11 | 12 | 11 |
| Ce | 22 | 26 | 23 | 23 | 26 | 27 | 24 |
| Y | 18 | 21.2 | 21.0 | 20 | 20 | 20 | 20 |
| Th | 3.0 | 3.0 | 5.0 | 4.0 | 4.0 | 2.0 | 3.0 |
| U | 1.0 | 2.0 | 2.0 | 1.0 | 1.0 | 2.0 | 1.0 |
| Zr | 81 | 100 | 101 | 99 | 93 | 96 | 96 |
| Nb | 4.0 | 5.0 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 |
| V | 222 | 235 | 235 | 234 | 230 | 232 | 231 |
| Cr | 108 | 80 | 76 | 77 | 83 | 77 | 86 |
| Mn | 1300 | 1480 | 1380 | 1380 | 1360 | 1340 | 1330 |
| Ni | 78 | 70 | 69 | 68 | 65 | 68 | 71 |
| Cu | 77 | 76 | 74 | 74 | 83 | 76 | 75 |
| Zn | 77 | 79 | 78 | 78 | 80 | 78 | 78 |
| Ga | 16.0 | 16.5 | 17.0 | 17.0 | 16.5 | 17.0 | 16.5 |

| | **84 219** | **84 220** | **84 221** | **84 222** | **84 223** | **84 224** | **84 225** |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 56.61 | 54.53 | 53.41 | 52.89 | 54.06 | 54.37 | 55.98 |
| $TiO_2$ | 1.03 | 0.63 | 0.62 | 0.64 | 0.63 | 0.70 | 0.79 |
| $Al_2O_3$ | 13.14 | 14.62 | 14.69 | 14.68 | 14.65 | 14.40 | 14.14 |
| $Fe_2O_3$ | 2.50 | 1.30 | 1.73 | 1.81 | 1.61 | 1.77 | 1.60 |
| FeO | 8.90 | 7.84 | 7.09 | 7.28 | 7.45 | 7.66 | 7.29 |
| MnO | 0.18 | 0.17 | 0.18 | 0.18 | 0.17 | 0.17 | 0.16 |
| MgO | 3.93 | 6.51 | 6.76 | 6.49 | 6.66 | 5.87 | 5.70 |
| CaO | 8.56 | 10.76 | 9.58 | 10.16 | 10.80 | 10.29 | 9.62 |
| $Na_2O$ | 2.19 | 1.94 | 2.50 | 2.45 | 1.90 | 1.94 | 2.08 |
| $K_2O$ | 1.31 | 0.86 | 1.09 | 1.01 | 0.90 | 1.00 | 1.21 |
| $P_2O_5$ | 0.16 | 0.09 | 0.09 | 0.09 | 0.09 | 0.10 | 0.11 |
| S | 0.07 | 0.05 | 0.02 | 0.02 | 0.03 | 0.05 | 0.04 |
| $H_2O+$ | 0.86 | 0.63 | 2.11 | 2.24 | 1.05 | 1.06 | 1.12 |
| $H_2O-$ | 0.20 | 0.22 | 0.56 | 0.73 | 0.46 | 0.46 | 0.55 |
| $CO_2$ | 0.20 | 0.21 | 0.14 | 0.12 | 0.12 | 0.13 | 0.14 |
| rest | 0.17 | 0.15 | 0.16 | 0.16 | 0.15 | 0.14 | 0.15 |
| | 100.01 | 100.51 | 100.73 | 100.95 | 100.73 | 100.11 | 100.68 |
| O=S | 0.03 | 0.02 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 |
| Total | 99.98 | 100.49 | 100.72 | 100.94 | 100.72 | 100.09 | 100.66 |
| | | | | | | | |
| Ba | 315 | 200 | 235 | 255 | 205 | 230 | 255 |
| Rb | 46.0 | 31.5 | 42.9 | 37.6 | 34.5 | 36.5 | 45.0 |
| Sr | 138 | 134 | 204.6 | 185.6 | 141 | 134 | 128 |
| Pb | 9 | 5 | 5 | 5 | 5 | 5 | 7 |
| La | 19 | 11 | 11 | 11 | 11 | 13 | 16 |
| Ce | 44 | 25 | 24 | 22 | 25 | 29 | 32 |
| Y | 30 | 20 | 19.8 | 20.5 | 19 | 21 | 23 |
| Th | 7.0 | 3.0 | 5.0 | 5.0 | 4.0 | 5.0 | 7.0 |
| U | 3.0 | 1.0 | 1.0 | 1.0 | 2.0 | 3.0 | 2.0 |
| Zr | 146 | 91 | 94 | 95 | 92 | 105 | 129 |
| Nb | 7.0 | 4.0 | 4.0 | 4.0 | 4.5 | 5.0 | 6.0 |
| V | 237 | 223 | 225 | 232 | 220 | 220 | 213 |
| Cr | 5 | 104 | 116 | 118 | 103 | 45 | 46 |
| Mn | 1370 | 1330 | 1370 | 1360 | 1290 | 1330 | 1270 |
| Ni | 35 | 73 | 79 | 81 | 77 | 62 | 61 |
| Cu | 116 | 75 | 72 | 75 | 78 | 80 | 85 |
| Zn | 100 | 77 | 79 | 81 | 75 | 79 | 76 |
| Ga | 19.5 | 16.5 | 16.5 | 17.0 | 17.0 | 16.5 | 17.0 |

| | **84 226** | **84 227** | **84 228** | **84 229** | **84 230** | **84 231** | **84 232** |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 53.82 | 52.91 | 53.38 | 53.58 | 53.22 | 53.55 | 53.13 |
| $TiO_2$ | 0.59 | 0.53 | 0.52 | 0.52 | 0.51 | 0.49 | 0.45 |
| $Al_2O_3$ | 14.96 | 14.97 | 13.34 | 12.80 | 13.72 | 13.43 | 13.60 |
| $Fe_2O_3$ | 1.73 | 1.15 | 1.65 | 1.21 | 1.62 | 1.41 | 1.17 |
| FeO | 7.08 | 7.38 | 7.07 | 7.29 | 6.98 | 7.14 | 7.07 |
| MnO | 0.16 | 0.17 | 0.18 | 0.18 | 0.17 | 0.18 | 0.18 |
| MgO | 6.62 | 7.31 | 9.02 | 9.51 | 8.72 | 9.09 | 9.30 |
| CaO | 11.24 | 11.83 | 11.53 | 11.63 | 11.36 | 11.43 | 11.83 |
| $Na_2O$ | 1.84 | 1.60 | 1.43 | 1.37 | 1.69 | 1.57 | 1.46 |
| $K_2O$ | 0.77 | 0.66 | 0.66 | 0.66 | 0.72 | 0.66 | 0.58 |
| $P_2O_5$ | 0.08 | 0.07 | 0.07 | 0.07 | 0.08 | 0.07 | 0.06 |
| S | 0.03 | 0.04 | 0.04 | 0.03 | 0.04 | | |
| $H_2O+$ | 0.77 | 0.57 | 0.55 | 0.53 | 0.76 | 0.78 | 0.74 |
| $H_2O-$ | 0.59 | 0.48 | 0.58 | 0.51 | 0.41 | 0.38 | 0.33 |
| $CO_2$ | 0.15 | 0.14 | 0.16 | 0.16 | 0.11 | 0.11 | 0.20 |
| rest | 0.13 | 0.14 | 0.15 | 0.16 | 0.15 | 0.15 | 0.15 |
| | 100.56 | 99.95 | 100.33 | 100.21 | 100.26 | 100.44 | 100.25 |
| O=S | 0.01 | 0.02 | 0.02 | 0.01 | 0.02 | | |
| Total | 100.55 | 99.93 | 100.31 | 100.20 | 100.24 | 100.44 | 100.25 |
| | | | | | | | |
| Ba | 185 | 155 | 160 | 145 | 170 | 150 | 145 |
| Rb | 27.0 | 24.0 | 23.0 | 23.0 | 25.5 | 24.5 | 21.0 |
| Sr | 121 | 117 | 102 | 98 | 112 | 109 | 116 |
| Pb | 5 | 5 | 4 | 4 | 4 | 5 | 4 |
| La | 11 | 9 | 9 | 8 | 9 | 9 | 8 |
| Ce | 24 | 22 | 18 | 18 | 20 | 19 | 14 |
| Y | 18 | 16 | 16 | 16 | 16 | 15 | 14 |
| Th | 1.0 | 2.0 | 2.0 | 2.0 | 3.0 | 3.0 | 2.0 |
| U | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Zr | 83 | 74 | 72 | 73 | 70 | 70 | 61 |
| Nb | 4.0 | 3.0 | 3.5 | 3.0 | 3.5 | 3.0 | 3.0 |
| V | 215 | 223 | 234 | 245 | 216 | 231 | 225 |
| Cr | 58 | 128 | 227 | 241 | 199 | 194 | 228 |
| Mn | 1250 | 1290 | 1360 | 1370 | 1280 | 1390 | 1360 |
| Ni | 70 | 83 | 112 | 119 | 104 | 108 | 115 |
| Cu | 73 | 66 | 61 | 57 | 57 | 56 | 50 |
| Zn | 71 | 69 | 69 | 68 | 66 | 68 | 64 |
| Ga | 16.0 | 15.0 | 15.0 | 13.5 | 15.0 | 13.5 | 13.5 |

| | **84 233** | **84 234** | **84 235** | **84 236** | **84 237** | **84 238** | **84 239** |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 53.61 | 53.21 | 52.87 | 53.33 | 53.20 | 51.63 | 53.41 |
| $TiO_2$ | 0.58 | 0.48 | 0.43 | 0.41 | 0.40 | 0.42 | 0.44 |
| $Al_2O_3$ | 13.52 | 13.04 | 12.67 | 13.28 | 12.95 | 12.91 | 12.62 |
| $Fe_2O_3$ | 1.75 | 1.18 | 1.19 | 1.40 | 0.75 | 1.38 | 1.77 |
| FeO | 7.24 | 7.28 | 7.01 | 6.70 | 7.24 | 6.87 | 6.64 |
| MnO | 0.18 | 0.18 | 0.18 | 0.17 | 0.18 | 0.18 | 0.18 |
| MgO | 8.15 | 9.72 | 10.54 | 10.27 | 10.76 | 10.91 | 10.51 |
| CaO | 11.01 | 11.71 | 11.97 | 12.11 | 12.09 | 12.28 | 11.77 |
| $Na_2O$ | 1.68 | 1.39 | 1.33 | 1.33 | 1.30 | 1.12 | 1.38 |
| $K_2O$ | 0.73 | 0.60 | 0.52 | 0.55 | 0.47 | 0.48 | 0.58 |
| $P_2O_5$ | 0.08 | 0.06 | 0.06 | 0.06 | 0.05 | 0.06 | 0.06 |
| S | | 0.02 | | 0.03 | | | 0.02 |
| $H_2O+$ | 1.30 | 0.69 | 0.68 | 0.53 | 0.70 | 1.53 | 0.69 |
| $H_2O-$ | 0.51 | 0.38 | 0.33 | 1.29 | 0.34 | 0.56 | 0.34 |
| $CO_2$ | 0.12 | 0.10 | 0.12 | 0.12 | 0.05 | 0.07 | 0.19 |
| rest | 0.15 | 0.15 | 0.16 | 0.15 | 0.16 | 0.16 | 0.16 |
| | 100.61 | 100.19 | 100.06 | 101.73 | 100.64 | 100.56 | 100.76 |
| O=S | | 0.01 | | 0.01 | | | 0.01 |
| Total | 100.61 | 100.18 | 100.06 | 101.72 | 100.64 | 100.56 | 100.75 |
| | | | | | | | |
| Ba | 165 | 145 | 125 | 130 | 115 | 125 | 130 |
| Rb | 26.5 | 20.5 | 18.5 | 20.0 | 17.0 | 17.5 | 20.5 |
| Sr | 121 | 101 | 92 | 100 | 98 | 106 | 97 |
| Pb | 5 | 4 | 2 | 4 | 2 | 3 | 4 |
| La | 10 | 8 | 7 | 7 | 7 | 7 | 7 |
| Ce | 24 | 19 | 15 | 16 | 15 | 15 | 19 |
| Y | 18 | 15 | 13 | 13 | 12 | 13 | 14 |
| Th | 4.0 | 2.0 | 3.0 | 3.0 | 2.0 | 3.0 | 3.0 |
| U | 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Zr | 83 | 65 | 57 | 56 | 54 | 55 | 60 |
| Nb | 4.0 | 2.5 | 2.0 | 2.5 | 2.5 | 2.5 | 2.5 |
| V | 232 | 235 | 236 | 231 | 234 | 238 | 237 |
| Cr | 156 | 253 | 292 | 280 | 314 | 306 | 294 |
| Mn | 1380 | 1380 | 1390 | 1340 | 1370 | 1390 | 1380 |
| Ni | 97 | 125 | 135 | 131 | 137 | 138 | 133 |
| Cu | 66 | 54 | 45 | 45 | 43 | 44 | 47 |
| Zn | 73 | 65 | 62 | 60 | 61 | 62 | 63 |
| Ga | 14.0 | 14.0 | 12.5 | 13.0 | 12.5 | 12.5 | 13.5 |

| | **84 240** | **84 241** | **84 242** | **84 243** | **84 244** | **84 245** | **84 246** |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 52.94 | 53.07 | 53.31 | 53.04 | 53.35 | 53.35 | 53.20 |
| $TiO_2$ | 0.41 | 0.42 | 0.44 | 0.40 | 0.42 | 0.47 | 0.41 |
| $Al_2O_3$ | 13.21 | 12.99 | 12.71 | 12.39 | 13.14 | 12.88 | 13.53 |
| $Fe_2O_3$ | 1.43 | 1.45 | 1.17 | 1.18 | 1.17 | 1.51 | 1.39 |
| FeO | 6.56 | 6.73 | 7.04 | 6.95 | 6.67 | 6.52 | 6.39 |
| MnO | 0.17 | 0.18 | 0.18 | 0.18 | 0.17 | 0.18 | 0.17 |
| MgO | 10.22 | 10.35 | 10.53 | 11.06 | 10.50 | 10.81 | 10.49 |
| CaO | 12.23 | 12.08 | 11.86 | 11.89 | 11.99 | 12.08 | 12.13 |
| $Na_2O$ | 1.26 | 1.37 | 1.34 | 1.31 | 1.36 | 1.30 | 1.25 |
| $K_2O$ | 0.49 | 0.51 | 0.59 | 0.50 | 0.52 | 0.49 | 0.52 |
| $P_2O_5$ | 0.06 | 0.06 | 0.06 | 0.05 | 0.06 | 0.06 | 0.06 |
| S | 0.03 | 0.02 | | | 0.02 | | 0.03 |
| $H_2O+$ | 0.59 | 0.81 | 0.62 | 0.83 | 0.59 | 0.76 | 0.60 |
| $H_2O-$ | 0.32 | 0.24 | 0.35 | 0.25 | 0.32 | 0.25 | 0.31 |
| $CO_2$ | 0.13 | 0.10 | 0.16 | 0.18 | 0.11 | 0.13 | 0.58 |
| rest | 0.15 | 0.15 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 |
| | 100.20 | 100.53 | 100.52 | 100.37 | 100.55 | 100.95 | 101.22 |
| O=S | 0.01 | 0.01 | | | 0.01 | | 0.01 |
| Total | 100.19 | 100.52 | 100.52 | 100.37 | 100.54 | 100.95 | 101.21 |
| | | | | | | | |
| Ba | 120 | 120 | 140 | 115 | 125 | 115 | 125 |
| Rb | 17.0 | 18.0 | 21.0 | 19.0 | 18.5 | 17.5 | 18.5 |
| Sr | 97 | 100 | 98 | 97 | 98 | 96 | 100 |
| Pb | 3 | 3 | 4 | 3 | 3 | 4 | 4 |
| La | 6 | 7 | 7 | 6 | 7 | 7 | 6 |
| Ce | 16 | 19 | 18 | 14 | 17 | 14 | 17 |
| Y | 13 | 13 | 14 | 13 | 13 | 12 | 13 |
| Th | 3.0 | 3.0 | 2.0 | 3.0 | 2.0 | 1.0 | 1.0 |
| U | 1.0 | 1.0 | 1.0 | 3.0 | 3.0 | 1.0 | 2.0 |
| Zr | 57 | 58 | 61 | 55 | 57 | 53 | 55 |
| Nb | 1.5 | 2.5 | 2.5 | 3.0 | 2.5 | 3.0 | 3.0 |
| V | 229 | 232 | 236 | 236 | 233 | 235 | 227 |
| Cr | 273 | 276 | 291 | 326 | 315 | 322 | 305 |
| Mn | 1330 | 1360 | 1370 | 1390 | 1340 | 1360 | 1310 |
| Ni | 131 | 133 | 136 | 141 | 136 | 139 | 133 |
| Cu | 45 | 46 | 47 | 44 | 42 | 44 | 41 |
| Zn | 60 | 61 | 63 | 63 | 61 | 62 | 59 |
| Ga | 13.0 | 13.0 | 12.5 | 13.0 | 13.5 | 12.5 | 13.5 |

| | **84 247** | **84 248** | **84 249** | **84 250** | **84 251** | **84 252** | **84 253** |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 53.00 | 53.01 | 53.05 | 53.15 | 53.55 | 53.09 | 53.26 |
| $TiO_2$ | 0.42 | 0.43 | 0.41 | 0.43 | 0.45 | 0.44 | 0.42 |
| $Al_2O_3$ | 11.97 | 13.32 | 12.41 | 14.00 | 11.56 | 13.43 | 12.81 |
| $Fe_2O_3$ | 1.46 | 1.19 | 1.13 | 1.30 | 1.10 | 1.13 | 1.23 |
| FeO | 7.05 | 6.99 | 6.98 | 6.60 | 7.52 | 6.83 | 6.80 |
| MnO | 0.18 | 0.17 | 0.18 | 0.16 | 0.19 | 0.17 | 0.17 |
| MgO | 11.01 | 10.03 | 10.98 | 9.46 | 10.93 | 9.77 | 10.62 |
| CaO | 11.74 | 11.91 | 11.83 | 12.10 | 11.76 | 12.26 | 11.92 |
| $Na_2O$ | 1.33 | 1.24 | 1.22 | 1.38 | 1.31 | 1.37 | 1.28 |
| $K_2O$ | 0.49 | 0.59 | 0.51 | 0.57 | 0.54 | 0.53 | 0.51 |
| $P_2O_5$ | 0.05 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| S | | 0.02 | | | | | 0.03 |
| $H_2O+$ | 0.64 | 0.64 | 0.76 | 0.61 | 0.69 | 0.86 | 0.60 |
| $H_2O-$ | 0.37 | 0.31 | 0.44 | 0.29 | 0.30 | 0.24 | 0.25 |
| $CO_2$ | 0.22 | 0.12 | 0.12 | 0.05 | 0.10 | 0.08 | 0.07 |
| rest | 0.16 | 0.15 | 0.16 | 0.14 | 0.16 | 0.14 | 0.16 |
| | 100.09 | 100.18 | 100.24 | 100.30 | 100.22 | 100.40 | 100.19 |
| O=S | | 0.01 | | | | | 0.01 |
| Total | 100.09 | 100.17 | 100.24 | 100.30 | 100.22 | 100.40 | 100.18 |
| | | | | | | | |
| Ba | 125 | 140 | 125 | 140 | 140 | 130 | 125 |
| Rb | 17.0 | 20.5 | 18.5 | 20.5 | 19.5 | 19.0 | 19.0 |
| Sr | 91 | 104 | 93 | 106 | 90 | 97 | 98 |
| Pb | 3 | 4 | 3 | 3 | 3 | 4 | 3 |
| La | 6 | 8 | 7 | 7 | 8 | 7 | 7 |
| Ce | 13 | 14 | 13 | 16 | 15 | 15 | 16 |
| Y | 13 | 14 | 13 | 14 | 14 | 14 | 13 |
| Th | 1.0 | 2.0 | 3.0 | 4.0 | 1.0 | 1.0 | 1.0 |
| U | 3.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Zr | 55 | 60 | 56 | 60 | 59 | 59 | 56 |
| Nb | 3.0 | 2.5 | 2.5 | 3.0 | 2.5 | 2.5 | 2.5 |
| V | 238 | 229 | 236 | 214 | 254 | 231 | 232 |
| Cr | 311 | 266 | 306 | 233 | 257 | 172 | 308 |
| Mn | 1390 | 1320 | 1370 | 1260 | 1450 | 1340 | 1340 |
| Ni | 142 | 126 | 140 | 116 | 141 | 125 | 135 |
| Cu | 50 | 45 | 43 | 46 | 50 | 42 | 44 |
| Zn | 65 | 63 | 63 | 60 | 66 | 61 | 62 |
| Ga | 13.0 | 12.5 | 12.5 | 14.5 | 12.5 | 13.5 | 13.0 |

| | **84 254** | **84 255** | **84 256** | **84 257** | **84 258** | **84 259** | **84 260** |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 53.15 | 52.49 | 52.68 | 53.61 | 52.76 | 53.22 | 52.85 |
| $TiO_2$ | 0.43 | 0.41 | 0.44 | 0.40 | 0.42 | 0.43 | 0.43 |
| $Al_2O_3$ | 13.87 | 13.40 | 12.13 | 11.03 | 13.25 | 12.60 | 12.75 |
| $Fe_2O_3$ | 1.32 | 1.47 | 1.54 | 1.60 | 1.08 | 1.17 | 1.15 |
| FeO | 6.43 | 6.95 | 7.10 | 7.03 | 7.03 | 7.17 | 7.15 |
| MnO | 0.16 | 0.17 | 0.18 | 0.19 | 0.17 | 0.18 | 0.17 |
| MgO | 9.59 | 10.23 | 10.90 | 11.94 | 10.01 | 10.56 | 10.32 |
| CaO | 12.12 | 12.29 | 11.89 | 11.92 | 12.15 | 11.92 | 11.86 |
| $Na_2O$ | 1.38 | 1.39 | 1.21 | 1.21 | 1.36 | 1.32 | 1.33 |
| $K_2O$ | 0.49 | 0.50 | 0.51 | 0.46 | 0.52 | 0.53 | 0.54 |
| $P_2O_5$ | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| S | 0.02 | 0.03 | 0.03 | | 0.02 | | |
| $H_2O+$ | 0.67 | 0.80 | 0.59 | 0.56 | 0.69 | 0.69 | 0.67 |
| $H_2O-$ | 0.27 | 0.24 | 0.25 | 0.28 | 0.30 | 0.29 | 0.23 |
| $CO_2$ | 0.12 | 0.09 | 0.11 | 0.11 | 0.09 | 0.09 | 0.08 |
| rest | 0.15 | 0.15 | 0.16 | 0.16 | 0.15 | 0.15 | 0.16 |
| | 100.23 | 100.67 | 99.78 | 100.56 | 100.06 | 100.38 | 99.75 |
| O=S | 0.01 | 0.01 | 0.01 | | 0.01 | | |
| Total | 100.22 | 100.66 | 99.77 | 100.56 | 100.05 | 100.38 | 99.75 |
| | | | | | | | |
| Ba | 125 | 115 | 120 | 115 | 125 | 125 | 130 |
| Rb | 17.0 | 17.5 | 18.0 | 16.5 | 18.5 | 19.5 | 20.5 |
| Sr | 102 | 98 | 90 | 81 | 96 | 92 | 95 |
| Pb | 5 | 4 | 4 | 3 | 4 | 3 | 4 |
| La | 8 | 7 | 7 | 6 | 7 | 7 | 7 |
| Ce | 15 | 13 | 15 | 14 | 15 | 16 | 14 |
| Y | 14 | 13 | 14 | 13 | 14 | 13 | 14 |
| Th | 3.0 | 2.0 | 3.0 | 2.0 | 2.0 | 1.0 | 1.0 |
| U | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Zr | 61 | 56 | 58 | 52 | 58 | 58 | 60 |
| Nb | 2.5 | 2.0 | 3.0 | 2.0 | 2.5 | 2.0 | 3.0 |
| V | 214 | 228 | 239 | 251 | 230 | 235 | 238 |
| Cr | 255 | 285 | 301 | 333 | 260 | 283 | 287 |
| Mn | 1270 | 1350 | 1390 | 1440 | 1320 | 1360 | 1350 |
| Ni | 119 | 129 | 139 | 151 | 128 | 133 | 135 |
| Cu | 46 | 45 | 49 | 46 | 48 | 46 | 49 |
| Zn | 61 | 63 | 65 | 64 | 63 | 62 | 64 |
| Ga | 14.0 | 13.0 | 12.5 | 11.5 | 14.0 | 13.0 | 12.5 |

| | **84 261** | **84 262** | **84 263** | **84 264** | **84 265** | **84 266** | **84 267** |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 52.90 | 53.54 | 53.46 | 53.82 | 53.98 | 54.99 | 54.81 |
| $TiO_2$ | 0.42 | 0.42 | 0.42 | 0.66 | 0.64 | 0.79 | 0.71 |
| $Al_2O_3$ | 12.41 | 12.72 | 10.94 | 15.99 | 16.18 | 16.45 | 14.86 |
| $Fe_2O_3$ | 1.05 | 1.03 | 1.18 | 1.85 | 1.59 | 1.58 | 1.71 |
| FeO | 7.47 | 7.13 | 7.52 | 7.27 | 7.28 | 7.78 | 8.12 |
| MnO | 0.18 | 0.18 | 0.19 | 0.18 | 0.15 | 0.16 | 0.18 |
| MgO | 10.78 | 10.72 | 12.00 | 5.07 | 5.05 | 3.66 | 5.38 |
| CaO | 12.05 | 12.05 | 11.65 | 10.88 | 11.43 | 10.39 | 10.51 |
| $Na_2O$ | 1.24 | 1.28 | 1.36 | 1.92 | 1.75 | 2.09 | 1.94 |
| $K_2O$ | 0.49 | 0.50 | 0.50 | 1.02 | 0.53 | 0.98 | 0.98 |
| $P_2O_5$ | 0.06 | 0.06 | 0.06 | 0.11 | 0.10 | 0.12 | 0.11 |
| S | | | | 0.04 | 0.04 | 0.06 | 0.06 |
| $H_2O+$ | 0.60 | 0.60 | 0.61 | 0.69 | 1.16 | 0.75 | 0.48 |
| $H_2O-$ | 0.27 | 0.26 | 0.27 | 0.58 | 0.30 | 0.47 | 0.38 |
| $CO_2$ | 0.10 | 0.10 | 0.12 | 0.07 | 0.08 | 0.06 | 0.10 |
| rest | 0.15 | 0.16 | 0.17 | 0.13 | 0.13 | 0.14 | 0.14 |
| | 100.17 | 100.75 | 100.45 | 100.28 | 100.39 | 100.47 | 100.47 |
| O=S | | | | 0.02 | 0.02 | 0.03 | 0.03 |
| Total | 100.17 | 100.75 | 100.45 | 100.26 | 100.37 | 100.44 | 100.44 |
| Ba | 120 | 120 | 115 | 230 | 205 | 250 | 225 |
| Rb | 16.5 | 17.5 | 17.5 | 35.5 | 12.5 | 26.5 | 36.0 |
| Sr | 91 | 92 | 79 | 143 | 170 | 148 | 124 |
| Pb | 5 | 3 | 4 | 7 | 7 | 7 | 6 |
| La | 6 | 6 | 7 | 13 | 12 | 14 | 14 |
| Ce | 15 | 14 | 14 | 28 | 23 | 33 | 28 |
| Y | 13 | 14 | 13 | 21 | 20 | 24 | 22 |
| Th | 2.0 | 2.0 | 2.0 | 4.0 | 4.0 | 6.0 | 1.0 |
| U | 2.0 | 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 2.0 |
| Zr | 55 | 58 | 56 | 104 | 96 | 122 | 108 |
| Nb | 3.0 | 2.5 | 2.5 | 4.5 | 4.0 | 5.5 | 5.0 |
| V | 234 | 236 | 257 | 200 | 209 | 200 | 225 |
| Cr | 287 | 325 | 375 | 17 | 14 | 1 | 11 |
| Mn | 1390 | 1360 | 1450 | 1380 | 1190 | 1210 | 1360 |
| Ni | 138 | 143 | 157 | 49 | 50 | 32 | 52 |
| Cu | 50 | 45 | 48 | 86 | 87 | 103 | 87 |
| Zn | 68 | 63 | 67 | 75 | 75 | 83 | 83 |
| Ga | 13.0 | 12.5 | 12.5 | 18.0 | 16.5 | 19.0 | 17.5 |

| | **84 268** | **84 269** | **84 270** | **84 271** | **84 272** | **84 273** | **84 274** |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 54.14 | 54.45 | 53.75 | 53.52 | 54.22 | 53.67 | 54.19 |
| $TiO_2$ | 0.70 | 0.65 | 0.66 | 0.69 | 0.69 | 0.64 | 0.61 |
| $Al_2O_3$ | 15.45 | 15.70 | 16.23 | 15.30 | 15.55 | 15.77 | 15.13 |
| $Fe_2O_3$ | 2.05 | 1.96 | 2.25 | 2.47 | 1.83 | 2.21 | 1.78 |
| FeO | 7.28 | 7.18 | 6.68 | 6.93 | 7.32 | 6.78 | 7.11 |
| MnO | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 |
| MgO | 5.12 | 5.61 | 5.29 | 5.78 | 5.60 | 5.62 | 6.10 |
| CaO | 10.80 | 11.12 | 11.25 | 11.12 | 10.31 | 10.65 | 10.93 |
| $Na_2O$ | 1.97 | 2.03 | 1.97 | 1.86 | 2.37 | 2.35 | 1.85 |
| $K_2O$ | 0.95 | 0.87 | 0.86 | 0.88 | 0.99 | 0.86 | 0.87 |
| $P_2O_5$ | 0.12 | 0.10 | 0.13 | 0.11 | 0.11 | 0.10 | 0.10 |
| S | 0.05 | 0.05 | 0.02 | 0.07 | 0.06 | 0.06 | |
| $H_2O+$ | 0.49 | 0.49 | 0.54 | 0.74 | 0.82 | 1.05 | 1.26 |
| $H_2O-$ | 0.42 | 0.44 | 0.42 | 0.66 | 0.41 | 0.33 | 0.34 |
| $CO_2$ | 0.11 | 0.13 | 0.03 | 0.16 | 0.12 | 0.13 | 0.11 |
| rest | 0.13 | 0.13 | 0.13 | 0.14 | 0.13 | 0.13 | 0.13 |
| | 99.94 | 101.07 | 100.37 | 100.59 | 100.69 | 100.51 | 100.67 |
| O=S | 0.02 | 0.02 | 0.01 | 0.03 | 0.03 | 0.03 | |
| Total | 99.92 | 101.05 | 100.36 | 100.56 | 100.66 | 100.48 | 100.67 |
| | | | | | | | |
| Ba | 210 | 205 | 205 | 205 | 230 | 210 | 210 |
| Rb | 34.0 | 31.0 | 30.5 | 31.5 | 36.0 | 31.5 | 31.0 |
| Sr | 126 | 125 | 127 | 130 | 123 | 118 | 119 |
| Pb | 6 | 6 | 6 | 5 | 6 | 5 | 6 |
| La | 13 | 11 | 11 | 13 | 12 | 11 | 11 |
| Ce | 30 | 26 | 25 | 26 | 28 | 24 | 26 |
| Y | 21 | 20 | 20 | 20 | 21 | 19 | 20 |
| Th | 8.0 | 4.0 | 4.0 | 4.0 | 5.0 | 4.0 | 4.0 |
| U | 2.0 | 1.0 | 1.0 | 3.0 | 1.0 | 2.0 | 1.0 |
| Zr | 105 | 94 | 96 | 96 | 100 | 93 | 96 |
| Nb | 5.5 | 4.0 | 5.0 | 4.0 | 4.0 | 4.5 | 5.0 |
| V | 217 | 211 | 209 | 231 | 211 | 202 | 206 |
| Cr | 12 | 19 | 20 | 24 | 25 | 29 | 39 |
| Mn | 1270 | 1260 | 1250 | 1270 | 1270 | 1220 | 1260 |
| Ni | 50 | 53 | 53 | 60 | 58 | 57 | 63 |
| Cu | 84 | 81 | 78 | 82 | 82 | 77 | 71 |
| Zn | 78 | 74 | 74 | 75 | 73 | 70 | 73 |
| Ga | 17.0 | 17.5 | 18.0 | 17.0 | 17.5 | 16.0 | 16.5 |

| | **84 275** | **84 276** | **84 277** | **84 278** | **84 279** | **84 280** | **84 281** |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 54.18 | 53.76 | 53.52 | 54.18 | 54.20 | 53.84 | 53.96 |
| $TiO_2$ | 0.67 | 0.66 | 0.64 | 0.65 | 0.66 | 0.67 | 0.67 |
| $Al_2O_3$ | 15.47 | 14.69 | 14.32 | 13.25 | 13.88 | 14.45 | 14.20 |
| $Fe_2O_3$ | 2.14 | 1.99 | 1.94 | 1.66 | 1.60 | 2.07 | 1.85 |
| FeO | 6.78 | 7.24 | 7.20 | 7.83 | 7.63 | 7.31 | 7.46 |
| MnO | 0.16 | 0.17 | 0.17 | 0.18 | 0.17 | 0.17 | 0.17 |
| MgO | 5.75 | 6.33 | 6.78 | 7.23 | 6.82 | 6.26 | 6.40 |
| CaO | 11.06 | 10.77 | 11.20 | 10.69 | 10.95 | 10.90 | 10.55 |
| $Na_2O$ | 1.90 | 1.77 | 1.66 | 1.81 | 1.87 | 1.77 | 2.19 |
| $K_2O$ | 0.88 | 0.86 | 0.79 | 0.87 | 0.87 | 0.85 | 0.90 |
| $P_2O_5$ | 0.10 | 0.09 | 0.09 | 0.09 | 0.10 | 0.11 | 0.10 |
| S | 0.03 | | | | | 0.02 | 0.04 |
| $H_2O+$ | 1.28 | 1.37 | 1.36 | 1.19 | 1.18 | 1.55 | 1.18 |
| $H_2O-$ | 0.30 | 0.36 | 0.38 | 0.26 | 0.26 | 0.34 | 0.28 |
| $CO_2$ | 0.13 | 0.11 | 0.11 | 0.07 | 0.10 | 0.07 | 0.12 |
| rest | 0.13 | 0.13 | 0.13 | 0.14 | 0.14 | 0.13 | 0.14 |
| | 100.96 | 100.30 | 100.29 | 100.10 | 100.43 | 100.51 | 100.21 |
| O=S | 0.01 | | | | | 0.01 | 0.02 |
| Total | 100.95 | 100.30 | 100.29 | 100.10 | 100.43 | 100.50 | 100.19 |
| | | | | | | | |
| Ba | 210 | 210 | 190 | 215 | 215 | 195 | 215 |
| Rb | 32.0 | 31.5 | 28.5 | 31.5 | 31.0 | 31.5 | 32.5 |
| Sr | 113 | 107 | 102 | 101 | 104 | 106 | 113 |
| Pb | 6 | 6 | 5 | 6 | 6 | 6 | 5 |
| La | 12 | 11 | 11 | 11 | 12 | 13 | 12 |
| Ce | 24 | 23 | 24 | 25 | 25 | 26 | 27 |
| Y | 20 | 20 | 19 | 20 | 20 | 20 | 20 |
| Th | 3.0 | 3.0 | 3.0 | 4.0 | 4.0 | 3.0 | 6.0 |
| U | 1.0 | 1.0 | 1.0 | 1.0 | 2.0 | 3.0 | 1.0 |
| Zr | 97 | 97 | 91 | 93 | 95 | 99 | 97 |
| Nb | 4.0 | 4.5 | 5.0 | 4.5 | 4.5 | 5.0 | 4.0 |
| V | 206 | 213 | 222 | 230 | 221 | 218 | 213 |
| Cr | 37 | 44 | 60 | 68 | 64 | 53 | 55 |
| Mn | 1230 | 1310 | 1310 | 1400 | 1350 | 1310 | 1320 |
| Ni | 59 | 66 | 77 | 81 | 74 | 68 | 71 |
| Cu | 72 | 77 | 71 | 74 | 73 | 75 | 79 |
| Zn | 73 | 77 | 74 | 79 | 74 | 76 | 75 |
| Ga | 17.0 | 17.5 | 16.0 | 15.0 | 16.5 | 17.0 | 16.0 |

| | **84 282** | **84 283** | **84 284** | **84 285** | **84 286** | **84 287** | **84 288** |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 53.51 | 53.57 | 53.52 | 53.39 | 53.12 | 53.2 | 53.47 |
| $TiO_2$ | 0.65 | 0.63 | 0.60 | 0.55 | 0.48 | 0.45 | 0.42 |
| $Al_2O_3$ | 15.13 | 14.88 | 15.17 | 15.25 | 13.07 | 12.56 | 12.46 |
| $Fe_2O_3$ | 2.56 | 2.22 | 2.10 | 1.74 | 1.69 | 1.99 | 1.64 |
| FeO | 6.47 | 6.79 | 6.58 | 6.46 | 6.62 | 6.29 | 6.49 |
| MnO | 0.15 | 0.17 | 0.16 | 0.16 | 0.17 | 0.18 | 0.17 |
| MgO | 5.93 | 6.17 | 6.56 | 7.18 | 9.55 | 10.40 | 11.04 |
| CaO | 10.96 | 11.03 | 11.39 | 11.62 | 11.95 | 11.83 | 11.54 |
| $Na_2O$ | 2.19 | 2.09 | 2.09 | 1.66 | 1.62 | 1.26 | 1.38 |
| $K_2O$ | 0.89 | 0.87 | 0.81 | 0.73 | 0.59 | 0.56 | 0.51 |
| $P_2O_5$ | 0.15 | 0.12 | 0.11 | 0.09 | 0.08 | 0.07 | 0.06 |
| S | 0.02 | 0.05 | 0.05 | 0.03 | 0.03 | | 0.03 |
| $H_2O+$ | 0.82 | 0.70 | 0.83 | 0.75 | 0.55 | 0.57 | 0.56 |
| $H_2O-$ | 0.44 | 0.33 | 0.40 | 0.43 | 0.39 | 0.39 | 0.57 |
| $CO_2$ | 0.10 | 0.12 | 0.15 | 0.09 | 0.11 | 0.23 | 0.14 |
| rest | 0.13 | 0.14 | 0.13 | 0.13 | 0.15 | 0.16 | 0.17 |
| | 100.10 | 99.88 | 100.65 | 100.26 | 100.17 | 100.14 | 100.65 |
| O=S | 0.01 | 0.02 | 0.02 | 0.01 | 0.01 | | 0.01 |
| Total | 100.09 | 99.86 | 100.63 | 100.25 | 100.16 | 100.14 | 100.64 |
| | | | | | | | |
| Ba | 210 | 205 | 195 | 175 | 140 | 130 | 120 |
| Rb | 32.0 | 31.0 | 29.0 | 26.0 | 21.0 | 20.0 | 18.0 |
| Sr | 117 | 119 | 116 | 111 | 93 | 91 | 87 |
| Pb | 6 | 6 | 6 | 5 | 4 | 3 | 3 |
| La | 12 | 11 | 10 | 10 | 8 | 8 | 8 |
| Ce | 26 | 22 | 23 | 21 | 18 | 16 | 16 |
| Y | 20 | 20 | 18 | 17 | 15 | 14 | 13 |
| Th | 4.0 | 2.0 | 3.0 | 3.0 | 5.0 | 3.0 | 4.0 |
| U | 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Zr | 94 | 95 | 86 | 78 | 66 | 62 | 59 |
| Nb | 4.0 | 4.5 | 4.0 | 4.0 | 3.0 | 2.5 | 2.0 |
| V | 203 | 210 | 207 | 206 | 233 | 231 | 224 |
| Cr | 51 | 60 | 81 | 120 | 255 | 317 | 372 |
| Mn | 1200 | 1290 | 1250 | 1250 | 1330 | 1360 | 1340 |
| Ni | 63 | 70 | 75 | 86 | 120 | 134 | 143 |
| Cu | 73 | 77 | 73 | 64 | 53 | 50 | 49 |
| Zn | 73 | 74 | 69 | 64 | 65 | 63 | 61 |
| Ga | 17.5 | 16.5 | 16.0 | 16.0 | 14.0 | 14.0 | 13.5 |

| | **84 289** | **84 290** | **84 291** | **84 292** | **84 293** | **84 294** | **84 295** |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 53.29 | 53.17 | 52.86 | 53.27 | 53.39 | 53.41 | 54.00 |
| $TiO_2$ | 0.43 | 0.42 | 0.45 | 0.48 | 0.51 | 0.55 | 0.56 |
| $Al_2O_3$ | 12.60 | 13.60 | 14.24 | 14.24 | 14.48 | 14.31 | 14.52 |
| $Fe_2O_3$ | 1.47 | 1.48 | 1.57 | 1.13 | 1.08 | 1.13 | 1.04 |
| FeO | 6.69 | 6.46 | 6.36 | 6.94 | 7.06 | 7.32 | 7.37 |
| MnO | 0.17 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 |
| MgO | 10.90 | 10.64 | 9.58 | 9.21 | 8.55 | 7.88 | 7.76 |
| CaO | 11.30 | 11.18 | 11.34 | 11.19 | 11.18 | 11.17 | 11.03 |
| $Na_2O$ | 1.26 | 1.40 | 1.41 | 1.39 | 1.53 | 1.77 | 1.74 |
| $K_2O$ | 0.53 | 0.52 | 0.60 | 0.64 | 0.68 | 0.74 | 0.75 |
| $P_2O_5$ | 0.06 | 0.09 | 0.08 | 0.08 | 0.08 | 0.17 | 0.10 |
| S | | | 0.03 | 0.03 | 0.03 | 0.04 | 0.04 |
| $H_2O+$ | 0.58 | 0.65 | 0.66 | 0.63 | 0.72 | 1.15 | 0.84 |
| $H_2O-$ | 0.42 | 0.53 | 0.53 | 0.48 | 0.44 | 0.34 | 0.29 |
| $CO_2$ | 0.28 | 0.08 | 0.18 | 0.14 | 0.18 | 0.15 | 0.15 |
| rest | 0.17 | 0.16 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 |
| | 100.15 | 100.54 | 100.20 | 100.16 | 100.22 | 100.44 | 100.50 |
| O=S | | | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 |
| Total | 100.15 | 100.54 | 100.19 | 100.15 | 100.21 | 100.42 | 100.48 |
| | | | | | | | |
| Ba | 125 | 130 | 140 | 145 | 155 | 175 | 180 |
| Rb | 18.5 | 17.0 | 21.5 | 22.5 | 24.0 | 25.5 | 27.5 |
| Sr | 99 | 119 | 101 | 99 | 103 | 99 | 107 |
| Pb | 4 | 3 | 3 | 4 | 4 | 4 | 4 |
| La | 7 | 6 | 8 | 9 | 9 | 10 | 12 |
| Ce | 13 | 14 | 15 | 17 | 20 | 22 | 20 |
| Y | 14 | 13 | 14 | 15 | 16 | 17 | 17 |
| Th | 2.0 | 3.0 | 3.0 | 3.0 | 4.0 | 2.0 | 5.0 |
| U | 1.0 | 1.0 | 2.0 | 1.0 | 1.0 | 2.0 | 1.0 |
| Zr | 59 | 57 | 65 | 68 | 74 | 80 | 80 |
| Nb | 3.0 | 2.5 | 3.0 | 3.0 | 3.0 | 4.0 | 4.0 |
| V | 223 | 202 | 203 | 211 | 208 | 211 | 208 |
| Cr | 366 | 349 | 302 | 274 | 241 | 190 | 180 |
| Mn | 1330 | 1250 | 1250 | 1260 | 1260 | 1270 | 1270 |
| Ni | 143 | 135 | 122 | 116 | 107 | 94 | 93 |
| Cu | 48 | 43 | 50 | 54 | 61 | 64 | 65 |
| Zn | 63 | 61 | 62 | 64 | 67 | 67 | 68 |
| Ga | 13.5 | 13.5 | 14.5 | 14.0 | 15.5 | 15.5 | 15.5 |

| | **84 296** | **84 297** | **84 298** | **84 299** | **84 300** | **84 301** | **84 302** |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 54.05 | 54.14 | 54.20 | 54.01 | 44.57 | 54.08 | 54.58 |
| $TiO_2$ | 0.58 | 0.60 | 0.61 | 0.63 | 0.67 | 0.63 | 0.66 |
| $Al_2O_3$ | 14.14 | 14.36 | 14.30 | 14.49 | 15.64 | 14.64 | 14.43 |
| $Fe_2O_3$ | 1.67 | 2.03 | 1.88 | 2.04 | 3.01 | 2.44 | 1.51 |
| FeO | 7.13 | 6.83 | 7.06 | 6.99 | 5.29 | 6.55 | 7.93 |
| MnO | 0.17 | 0.17 | 0.17 | 0.17 | 0.24 | 0.17 | 0.17 |
| MgO | 7.77 | 7.29 | 7.13 | 6.78 | 3.91 | 6.48 | 6.12 |
| CaO | 10.51 | 10.63 | 10.85 | 10.41 | 13.24 | 10.26 | 10.51 |
| $Na_2O$ | 1.99 | 1.98 | 1.86 | 2.07 | 2.14 | 1.76 | 1.86 |
| $K_2O$ | 0.81 | 0.80 | 0.84 | 0.94 | 0.84 | 0.86 | 0.72 |
| $P_2O_5$ | 0.12 | 0.13 | 0.13 | 0.14 | 0.09 | 0.09 | 0.10 |
| S | 0.04 | | 0.04 | | 0.02 | 0.03 | 0.05 |
| $H_2O$+ | 0.94 | 0.90 | 0.73 | 0.92 | 3.04 | 1.20 | 1.08 |
| $H_2O$- | 0.46 | 0.41 | 0.53 | 0.64 | 1.30 | 0.85 | 0.42 |
| $CO_2$ | 0.22 | 0.18 | 0.19 | 0.15 | 6.56 | 0.25 | 0.49 |
| rest | 0.15 | 0.15 | 0.15 | 0.17 | 0.17 | 0.15 | 0.14 |
| | 100.75 | 100.60 | 100.67 | 100.55 | 100.73 | 100.44 | 100.77 |
| O=S | 0.02 | | 0.02 | | 0.01 | 0.01 | 0.02 |
| Total | 100.73 | 100.60 | 100.65 | 100.55 | 100.72 | 100.43 | 100.75 |
| | | | | | | | |
| Ba | 185 | 190 | 215 | 400 | 225 | 230 | 205 |
| Rb | 30.0 | 30.0 | 27.0 | 33.0 | 28.0 | 30.7 | 24.5 |
| Sr | 109 | 137 | 132 | 147 | 199 | 150.3 | 134 |
| Pb | 6 | 5 | 6 | 6 | 6 | 6 | 6 |
| La | 11 | 10 | 12 | 12 | 11 | 11 | 12 |
| Ce | 22 | 22 | 23 | 23 | 26 | 26 | 24 |
| Y | 18 | 19 | 19 | 20 | 21 | 20.2 | 21 |
| Th | 2.0 | 5.0 | 3.0 | 3.0 | 4.0 | 4.0 | 3.0 |
| U | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Zr | 85 | 89 | 91 | 94 | 102 | 97 | 98 |
| Nb | 4.0 | 4.0 | 4.5 | 4.0 | 4.5 | 4.5 | 4.5 |
| V | 222 | 220 | 218 | 222 | 270 | 227 | 234 |
| Cr | 154 | 134 | 131 | 110 | 129 | 107 | 76 |
| Mn | 1290 | 1300 | 1290 | 1340 | 1870 | 1320 | 1330 |
| Ni | 90 | 83 | 83 | 77 | 82 | 76 | 71 |
| Cu | 66 | 69 | 73 | 75 | 76 | 75 | 74 |
| Zn | 71 | 72 | 73 | 76 | 80 | 77 | 81 |
| Ga | 16.0 | 16.0 | 15.0 | 16.5 | 17.0 | 16.5 | 17.5 |

| | **84 303** | **84 304** | **84 305** | **84 306** | **84 307** | **84 308** | **84 309** |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 55.27 | 55.02 | 54.95 | 54.24 | 53.95 | 54.48 | 53.84 |
| $TiO_2$ | 0.71 | 0.66 | 0.68 | 0.62 | 0.70 | 0.64 | 0.60 |
| $Al_2O_3$ | 15.14 | 14.42 | 14.74 | 14.76 | 17.44 | 14.71 | 15.57 |
| $Fe_2O_3$ | 1.96 | 1.52 | 1.99 | 1.47 | 2.44 | 1.39 | 1.73 |
| FeO | 6.25 | 7.74 | 6.45 | 7.65 | 5.46 | 7.93 | 6.73 |
| MnO | 0.13 | 0.17 | 0.14 | 0.16 | 0.12 | 0.17 | 0.16 |
| MgO | 5.49 | 6.20 | 5.75 | 6.17 | 4.50 | 6.48 | 6.33 |
| CaO | 10.43 | 10.50 | 10.53 | 10.79 | 10.84 | 10.71 | 11.28 |
| $Na_2O$ | 1.81 | 1.77 | 1.94 | 1.86 | 2.06 | 1.80 | 1.88 |
| $K_2O$ | 0.70 | 0.88 | 0.76 | 0.81 | 0.96 | 0.69 | 0.69 |
| $P_2O_5$ | 0.10 | 0.09 | 0.10 | 0.09 | 0.12 | 0.09 | 0.09 |
| S | 0.05 | 0.04 | 0.04 | 0.04 | 0.05 | 0.05 | 0.05 |
| $H_2O+$ | 1.26 | 0.75 | 1.27 | 0.62 | 1.11 | 0.75 | 0.67 |
| $H_2O-$ | 0.87 | 0.32 | 0.70 | 0.27 | 0.69 | 0.35 | 0.26 |
| $CO_2$ | 0.56 | 0.19 | 0.27 | 0.17 | 0.16 | 0.14 | 0.16 |
| rest | 0.15 | 0.15 | 0.15 | 0.14 | 0.14 | 0.14 | 0.13 |
| | 100.88 | 100.42 | 100.46 | 99.86 | 100.74 | 100.52 | 100.17 |
| O=S | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| Total | 100.86 | 100.40 | 100.44 | 99.84 | 100.72 | 100.50 | 100.15 |
| Ba | 225 | 215 | 215 | 205 | 220 | 190 | 185 |
| Rb | 26.5 | 30.5 | 30.0 | 29.5 | 35.0 | 28.5 | 27.0 |
| Sr | 151 | 136 | 146 | 136 | 151 | 127 | 134 |
| Pb | 6 | 5 | 6 | 5 | 6 | 6 | 5 |
| La | 12 | 11 | 12 | 11 | 12 | 11 | 9 |
| Ce | 26 | 25 | 25 | 18 | 27 | 25 | 20 |
| Y | 19 | 20 | 20 | 19 | 20 | 19 | 17 |
| Th | 5.0 | 5.0 | 4.0 | 3.0 | 4.0 | 4.0 | 2.0 |
| U | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 2.0 |
| Zr | 100 | 100 | 106 | 91 | 101 | 93 | 84 |
| Nb | 4.5 | 5.0 | 5.0 | 4.5 | 4.5 | 4.0 | 4.0 |
| V | 245 | 229 | 246 | 228 | 213 | 225 | 217 |
| Cr | 78 | 76 | 79 | 78 | 30 | 103 | 68 |
| Mn | 1040 | 1300 | 1090 | 1270 | 960 | 1280 | 1210 |
| Ni | 70 | 67 | 70 | 68 | 47 | 73 | 73 |
| Cu | 76 | 75 | 78 | 81 | 77 | 77 | 64 |
| Zn | 86 | 79 | 85 | 79 | 76 | 77 | 71 |
| Ga | 17.5 | 16.5 | 17.5 | 17.0 | 17.5 | 16.5 | 17.5 |

| | **84 310** | **84 311** | **84 312** | **84 313** | **84 314** | **84 315** | **84 316** |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 55.65 | 54.12 | 53.27 | 54.65 | 53.37 | 54.24 | 54.23 |
| $TiO_2$ | 0.77 | 0.67 | 0.57 | 0.62 | 0.52 | 0.57 | 0.58 |
| $Al_2O_3$ | 15.77 | 13.87 | 14.88 | 11.58 | 15.91 | 13.76 | 14.93 |
| $Fe_2O_3$ | 1.68 | 1.18 | 1.03 | 1.18 | 0.78 | 0.97 | 0.94 |
| FeO | 7.98 | 8.65 | 8.09 | 8.75 | 7.17 | 7.97 | 7.63 |
| MnO | 0.16 | 0.18 | 0.17 | 0.19 | 0.15 | 0.18 | 0.17 |
| MgO | 3.93 | 6.58 | 6.70 | 8.99 | 6.87 | 8.16 | 7.21 |
| CaO | 9.81 | 10.45 | 11.08 | 10.66 | 11.28 | 11.11 | 11.05 |
| $Na_2O$ | 2.42 | 1.92 | 1.86 | 1.41 | 1.98 | 1.59 | 1.63 |
| $K_2O$ | 0.94 | 0.92 | 0.73 | 0.73 | 0.74 | 0.68 | 0.75 |
| $P_2O_5$ | 0.14 | 0.11 | 0.08 | 0.09 | 0.07 | 0.09 | 0.09 |
| S | 0.06 | 0.05 | 0.04 | 0.04 | 0.04 | 0.04 | 0.06 |
| $H_2O+$ | 0.97 | 0.94 | 0.70 | 0.77 | 0.69 | 0.69 | 0.61 |
| $H_2O-$ | 0.29 | 0.28 | 0.29 | 0.40 | 0.22 | 0.28 | 0.25 |
| $CO_2$ | 0.15 | 0.14 | 0.12 | 0.14 | 0.19 | 0.16 | 0.17 |
| rest | 0.14 | 0.14 | 0.13 | 0.16 | 0.13 | 0.15 | 0.14 |
| | 100.86 | 100.20 | 99.74 | 100.36 | 100.11 | 100.64 | 100.44 |
| O=S | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.03 |
| Total | 100.83 | 100.18 | 99.72 | 100.34 | 100.09 | 100.62 | 100.41 |
| | | | | | | | |
| Ba | 255 | 205 | 185 | 170 | 175 | 165 | 175 |
| Rb | 31.5 | 35.5 | 26.0 | 24.0 | 30.5 | 22.5 | 25.0 |
| Sr | 143 | 120 | 124 | 92 | 132 | 108 | 118 |
| Pb | 7 | 6 | 5 | 5 | 4 | 5 | 5 |
| La | 15 | 12 | 10 | 10 | 10 | 9 | 10 |
| Ce | 35 | 26 | 23 | 22 | 18 | 20 | 20 |
| Y | 24 | 20 | 17 | 19 | 15 | 17 | 18 |
| Th | 3.0 | 5.0 | 1.0 | 3.0 | 5.0 | 3.0 | 3.0 |
| U | 1.0 | 1.0 | 1.0 | 3.0 | 1.0 | 1.0 | 1.0 |
| Zr | 120 | 93 | 77 | 88 | 73 | 78 | 84 |
| Nb | 5.5 | 4.5 | 3.5 | 3.5 | 2.5 | 3.5 | 4.5 |
| V | 203 | 239 | 220 | 259 | 201 | 232 | 224 |
| Cr | 11 | 47 | 78 | 178 | 120 | 166 | 137 |
| Mn | 1250 | 1420 | 1300 | 1490 | 1200 | 1380 | 1300 |
| Ni | 37 | 69 | 73 | 109 | 79 | 98 | 86 |
| Cu | 112 | 83 | 73 | 72 | 59 | 66 | 64 |
| Zn | 87 | 82 | 76 | 82 | 65 | 74 | 72 |
| Ga | 18.0 | 16.5 | 17.0 | 14.5 | 17.5 | 15.5 | 17.0 |

| | **84 317** | **84 318** | **84 319** | **84 320** | **84 321** | **84 322** | **84 323** |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 54.15 | 54.54 | 54.45 | 54.92 | 54.94 | 55.08 | 55.17 |
| $TiO_2$ | 0.56 | 0.60 | 0.61 | 0.64 | 0.66 | 0.67 | 0.67 |
| $Al_2O_3$ | 14.34 | 14.30 | 14.18 | 14.43 | 14.41 | 14.52 | 14.48 |
| $Fe_2O_3$ | 0.94 | 0.97 | 0.77 | 1.00 | 1.02 | 0.99 | 1.19 |
| FeO | 7.65 | 7.82 | 8.09 | 8.00 | 8.08 | 8.08 | 7.81 |
| MnO | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 |
| MgO | 7.80 | 7.55 | 7.36 | 6.57 | 6.38 | 6.30 | 6.26 |
| CaO | 11.06 | 10.90 | 10.68 | 10.57 | 10.45 | 10.46 | 10.44 |
| $Na_2O$ | 1.60 | 1.80 | 1.73 | 1.89 | 1.80 | 1.64 | 1.87 |
| $K_2O$ | 0.71 | 0.73 | 0.81 | 0.88 | 0.96 | 0.93 | 0.92 |
| $P_2O_5$ | 0.08 | 0.09 | 0.09 | 0.09 | 0.10 | 0.10 | 0.10 |
| S | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| $H_2O+$ | 0.60 | 0.60 | 0.68 | 0.60 | 0.86 | 0.72 | 0.78 |
| $H_2O-$ | 0.26 | 0.25 | 0.17 | 0.23 | 0.26 | 0.25 | 0.25 |
| $CO_2$ | 0.11 | 0.14 | 0.13 | 0.20 | 0.21 | 0.25 | 0.26 |
| rest | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 |
| | 100.23 | 100.66 | 100.12 | 100.39 | 100.50 | 100.36 | 100.57 |
| O=S | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| Total | 100.21 | 100.64 | 100.10 | 100.37 | 100.48 | 100.34 | 100.55 |
| Ba | 170 | 180 | 200 | 210 | 220 | 240 | 230 |
| Rb | 23.0 | 24.5 | 30.0 | 31.0 | 34.5 | 33.0 | 32.7 |
| Sr | 113 | 117 | 123 | 129 | 137 | 130 | 128.9 |
| Pb | 4 | 5 | 5 | 6 | 5 | 5 | 6 |
| La | 10 | 10 | 10 | 10 | 11 | 12 | 11 |
| Ce | 20 | 21 | 25 | 25 | 24 | 26 | 27 |
| Y | 17 | 18 | 19 | 19 | 20 | 20 | 20.4 |
| Th | 3.0 | 2.0 | 4.0 | 3.0 | 4.0 | 8.0 | 6.0 |
| U | 1.0 | 2.0 | 1.0 | 1.0 | 2.0 | 1.0 | 1.0 |
| Zr | 81 | 85 | 88 | 95 | 98 | 100 | 101 |
| Nb | 3.0 | 3.5 | 4.0 | 4.0 | 4.5 | 4.5 | 4.5 |
| V | 226 | 231 | 225 | 232 | 226 | 230 | 235 |
| Cr | 169 | 163 | 148 | 99 | 86 | 79 | 80 |
| Mn | 1300 | 1310 | 1310 | 1290 | 1300 | 1290 | 1290 |
| Ni | 97 | 91 | 86 | 73 | 72 | 69 | 71 |
| Cu | 64 | 68 | 71 | 72 | 74 | 72 | 72 |
| Zn | 72 | 74 | 74 | 77 | 78 | 78 | 79 |
| Ga | 15.5 | 16.0 | 16.0 | 16.5 | 17.0 | 16.0 | 17.0 |

| | **84 324** |
|---|---|
| $SiO_2$ | 54.87 |
| $TiO_2$ | 0.66 |
| $Al_2O_3$ | 14.41 |
| $Fe_2O_3$ | 1.15 |
| FeO | 7.71 |
| MnO | 0.17 |
| MgO | 6.16 |
| CaO | 10.29 |
| $Na_2O$ | 1.81 |
| $K_2O$ | 0.88 |
| $P_2O_5$ | 0.10 |
| S | 0.05 |
| $H_2O+$ | 0.91 |
| $H_2O-$ | 0.40 |
| $CO_2$ | 0.66 |
| rest | 0.15 |
| | 100.38 |
| O=S | 0.02 |
| Total | 100.36 |
| | |
| Ba | 235 |
| Rb | 32.4 |
| Sr | 129.2 |
| Pb | 6 |
| La | 11 |
| Ce | 25 |
| Y | 20.8 |
| Th | 5.0 |
| U | 1.0 |
| Zr | 101 |
| Nb | 4.5 |
| V | 233 |
| Cr | 79 |
| Mn | 1280 |
| Ni | 68 |
| Cu | 73 |
| Zn | 80 |
| Ga | 17.0 |

# XRF, INAA AND WET-CHEMICAL ANALYSES OF CHILLED MARGIN DOLERITES

| | **84 101** | **84 106** | **84 107** | **84 108** | **84 109** | **84 111** | **84 115** |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 54.42 | 54.00 | 53.73 | 54.02 | 54.43 | 53.99 | 53.94 |
| $TiO_2$ | 0.63 | 0.63 | 0.63 | 0.63 | 0.66 | 0.64 | 0.62 |
| $Al_2O_3$ | 14.54 | 14.69 | 14.60 | 14.66 | 14.42 | 14.66 | 14.45 |
| $Fe_2O_3$ | 0.86 | 1.03 | 1.47 | 1.19 | 1.59 | 1.22 | 1.36 |
| FeO | 7.99 | 7.83 | 7.53 | 7.70 | 7.60 | 7.59 | 7.49 |
| MnO | 0.17 | 0.19 | 0.19 | 0.18 | 0.18 | 0.17 | 0.17 |
| MgO | 6.68 | 6.71 | 6.78 | 6.78 | 6.46 | 6.83 | 6.76 |
| CaO | 11.05 | 10.69 | 10.59 | 10.53 | 10.04 | 10.32 | 10.30 |
| $CaO_{INAA}$ | 11.1 | 10.9 | 11.0 | 10.3 | 10.4 | 10.5 | 10.5 |
| $Na_2O$ | 1.99 | 2.15 | 2.09 | 2.14 | 2.14 | 1.89 | 2.14 |
| $Na_2O_{INAA}$ | 1.89 | 2.06 | 1.90 | 1.94 | 1.98 | 1.81 | 2.13 |
| $K_2O$ | 0.60 | 0.85 | 0.83 | 0.84 | 0.98 | 1.02 | 0.93 |
| $P_2O_5$ | 0.09 | 0.09 | 0.09 | 0.09 | 0.10 | 0.09 | 0.09 |
| S | 0.04 | 0.03 | 0.03 | 0.07 | 0.05 | 0.05 | 0.09 |
| $H_2O+$ | 0.93 | 0.62 | 0.80 | 0.93 | 1.35 | 1.10 | 0.86 |
| $H_2O-$ | 0.26 | 0.53 | 0.68 | 0.58 | 0.49 | 0.44 | 0.36 |
| $CO_2$ | 0.20 | 0.16 | 0.15 | 0.22 | 0.14 | 0.14 | 0.20 |
| rest | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.16 | 0.15 |
| | 100.60 | 100.35 | 100.34 | 100.71 | 100.78 | 100.31 | 99.91 |
| O=S | 0.02 | 0.01 | 0.01 | 0.03 | 0.02 | 0.02 | 0.04 |
| Total | 100.58 | 100.34 | 100.33 | 100.68 | 100.76 | 100.29 | 99.87 |
| | | | | | | | |
| Q | 6.59 | 5.03 | 5.59 | 5.40 | 6.77 | 6.27 | 5.67 |
| Or | 3.55 | 5.02 | 4.91 | 4.96 | 5.79 | 6.03 | 5.50 |
| Ab | 16.84 | 18.19 | 17.69 | 18.11 | 18.11 | 15.99 | 18.11 |
| An | 28.97 | 27.92 | 28.00 | 27.91 | 26.85 | 28.5 | 27.08 |
| Di | 20.74 | 20.11 | 19.59 | 19.44 | 18.28 | 18.09 | 19.17 |
| Hy | 19.68 | 19.68 | 19.22 | 19.81 | 19.02 | 20.34 | 19.37 |
| Mt | 1.25 | 1.49 | 2.13 | 1.73 | 2.31 | 1.77 | 1.97 |
| Il | 1.20 | 1.20 | 1.20 | 1.20 | 1.25 | 1.22 | 1.18 |
| Ap | 0.21 | 0.21 | 0.21 | 0.21 | 0.23 | 0.21 | 0.21 |
| rest | 1.39 | 1.31 | 1.63 | 1.73 | 1.98 | 1.68 | 1.42 |
| Total | 100.42 | 100.16 | 100.17 | 100.5 | 100.59 | 100.10 | 99.68 |
| | | | | | | | |
| Mg# | 61.0 | 61.1 | 61.1 | 61.3 | 59.5 | 61.7 | 61.4 |

| | **84 101** | **84 106** | **84 107** | **84 108** | **84 109** | **84 111** | **84 115** |
|---|---|---|---|---|---|---|---|
| $\mathrm{Cs}_{\mathrm{INAA}}$ | 1.01 | 1.03 | 1.01 | 1.03 | 0.63 | 0.88 | 0.89 |
| Ba | 190 | 205 | 200 | 225 | 195 | 305 | 200 |
| $\mathrm{Ba}_{\mathrm{INAA}}$ | 182 | 187 | 187 | 198 | 211 | 276 | 182 |
| Rb | 17.8 | 30.6 | 29.3 | 39.1 | 33.2 | 33.7 | 35.2 |
| $\mathrm{Rb}_{\mathrm{INAA}}$ | 17 | 24 | 27 | 27 | 31 | 30 | 31 |
| $\mathrm{Rb}_{\mathrm{ID}}$ | 17.0 | 28.9 | 27.3 | 28.3 | 35.0 | | |
| Sr | 132.2 | 121.4 | 119.0 | 124.4 | 178.6 | 155.5 | 142.0 |
| $\mathrm{Sr}_{\mathrm{ID}}$ | 125.0 | 115.1 | 109.2 | 120.1 | 185.1 | | |
| Pb | 7 | 5 | 6 | 5 | 5 | 6 | 6 |
| La | 11 | 11 | 10 | 11 | 11 | 11 | 11 |
| $\mathrm{La}_{\mathrm{INAA}}$ | 10.9 | 10.6 | 10.9 | 10.9 | 11.4 | 10.8 | 10.8 |
| Ce | 24 | 23 | 24 | 24 | 25 | 22 | 24 |
| $\mathrm{Ce}_{\mathrm{INAA}}$ | 24.4 | 23.4 | 24.3 | 23.2 | 25.6 | 23.2 | 24.2 |
| $\mathrm{Nd}_{\mathrm{INAA}}$ | 12.6 | 11.8 | 11.8 | 11.5 | 13.5 | 11.5 | 11.7 |
| $\mathrm{Nd}_{\mathrm{ID}}$ | 9.50 | 11.94 | 12.40 | 12.12 | 13.44 | | |
| $\mathrm{Sm}_{\mathrm{INAA}}$ | 3.02 | 3.02 | 3.03 | 3.03 | 3.20 | 3.06 | 3.05 |
| $\mathrm{Sm}_{\mathrm{ID}}$ | 2.92 | 2.83 | 2.93 | 2.86 | 3.17 | | |
| $\mathrm{Eu}_{\mathrm{INAA}}$ | 0.830 | 0.806 | 0.819 | 0.806 | 0.876 | 0.794 | 0.821 |
| $\mathrm{Gd}_{\mathrm{INAA}}$ | 3.1 | 3.0 | 3.1 | 3.1 | 3.2 | 2.9 | 3.1 |
| $\mathrm{Tb}_{\mathrm{INAA}}$ | 0.59 | 0.57 | 0.59 | 0.59 | 0.60 | 0.56 | 0.56 |
| $\mathrm{Ho}_{\mathrm{INAA}}$ | 0.79 | 0.81 | 0.79 | 0.74 | 0.80 | 0.85 | 0.81 |
| $\mathrm{Yb}_{\mathrm{INAA}}$ | 2.38 | 2.40 | 2.42 | 2.38 | 2.49 | 2.34 | 2.40 |
| $\mathrm{Lu}_{\mathrm{INAA}}$ | 0.368 | 0.358 | 0.365 | 0.368 | 0.373 | 0.357 | 0.360 |
| Y | 21.1 | 20.3 | 20.7 | 20.4 | 20.8 | 20.5 | 20.2 |
| Th | 4 | 4 | 3 | 4 | 3 | 4 | 3 |
| $\mathrm{Th}_{\mathrm{INAA}}$ | 3.5 | 3.5 | 3.4 | 3.3 | 3.5 | 3.3 | 3.6 |
| $\mathrm{U}_{\mathrm{INAA}}$ | 1.1 | 1.1 | 1.2 | 1.1 | 1.0 | 1.0 | 1.0 |
| Zr | 94 | 94 | 96 | 95 | 100 | 95 | 94 |
| $\mathrm{Hf}_{\mathrm{INAA}}$ | 1.9 | 1.8 | 1.9 | 1.8 | 2.0 | 1.8 | 1.9 |
| Nb | 4.0 | 5.0 | 4.5 | 5.0 | 4.5 | 5.0 | 4.5 |
| $\mathrm{Sc}_{\mathrm{INAA}}$ | 40.6 | 41.0 | 41.2 | 40.9 | 42.3 | 40.5 | 40.9 |
| V | 223 | 231 | 221 | 222 | 238 | 225 | 222 |
| Cr | 113 | 121 | 112 | 110 | 82 | 114 | 114 |
| $\mathrm{Cr}_{\mathrm{INAA}}$ | 120 | 124 | 119 | 119 | 83 | 114 | 123 |
| Mn | 1340 | 1450 | 1470 | 1410 | 1390 | 1320 | 1300 |
| Co | 49 | 49 | 48 | 49 | 49 | 49 | 47 |
| Ni | 79 | 83 | 80 | 78 | 71 | 80 | 79 |
| Cu | 78 | 79 | 75 | 74 | 73 | 77 | 74 |
| Zn | 82 | 80 | 78 | 79 | 81 | 79 | 77 |
| Ga | 16.0 | 15.5 | 16.0 | 15.5 | 17.0 | 17.0 | 16.5 |

| | **84 128** | **84 129** | **84 138** | **84 140** | **84 141** | **84 143** | **84 144** |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 54.21 | 54.15 | 54.61 | 53.83 | 54.41 | 54.81 | 54.08 |
| $TiO_2$ | 0.64 | 0.61 | 0.64 | 0.63 | 0.63 | 0.66 | 0.63 |
| $Al_2O_3$ | 14.66 | 14.66 | 14.86 | 14.57 | 14.70 | 14.45 | 14.66 |
| $Fe_2O_3$ | 0.76 | 0.57 | 0.42 | 1.12 | 1.20 | 1.53 | 0.97 |
| FeO | 8.02 | 8.16 | 8.42 | 7.71 | 7.71 | 7.70 | 7.92 |
| MnO | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.18 | 0.17 |
| MgO | 6.75 | 6.61 | 6.66 | 6.65 | 6.84 | 6.34 | 6.78 |
| CaO | 10.99 | 10.97 | 10.91 | 10.74 | 10.79 | 9.73 | 10.84 |
| $CaO_{INAA}$ | 11.3 | 11.4 | 11.0 | 10.9 | 10.8 | 9.9 | 10.8 |
| $Na_2O$ | 1.74 | 1.88 | 1.87 | 1.78 | 1.95 | 2.05 | 2.11 |
| $Na_2O_{INAA}$ | 1.73 | 1.81 | 1.80 | 1.75 | 1.73 | 1.97 | 1.89 |
| $K_2O$ | 0.68 | 0.75 | 0.86 | 0.82 | 0.83 | 0.98 | 0.84 |
| $P_2O_5$ | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.10 | 0.09 |
| S | 0.04 | 0.04 | 0.05 | 0.05 | 0.04 | 0.03 | 0.04 |
| $H_2O$ + | 1.13 | 0.74 | 0.43 | 0.71 | 0.76 | 0.92 | 0.54 |
| $H_2O$ - | 0.22 | 0.25 | 0.23 | 0.52 | 0.29 | 0.43 | 0.35 |
| $CO_2$ | 0.16 | 0.13 | 0.15 | 0.15 | 0.21 | 0.14 | 0.18 |
| rest | 0.15 | 0.14 | 0.15 | 0.14 | 0.15 | 0.15 | 0.14 |
| | 100.41 | 99.92 | 100.52 | 99.68 | 100.77 | 100.20 | 100.34 |
| O=S | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.02 |
| Total | 100.39 | 99.90 | 100.50 | 99.66 | 100.75 | 100.19 | 100.32 |
| | | | | | | | |
| Q | 7.17 | 6.23 | 6.01 | 7.01 | 6.35 | 7.98 | 5.01 |
| Or | 4.02 | 4.43 | 5.08 | 4.85 | 4.91 | 5.79 | 4.96 |
| Ab | 14.72 | 15.91 | 15.82 | 15.06 | 16.5 | 17.35 | 17.85 |
| An | 30.18 | 29.35 | 29.61 | 29.34 | 28.91 | 27.33 | 28.05 |
| Di | 19.50 | 20.14 | 19.70 | 19.14 | 19.68 | 16.64 | 20.62 |
| Hy | 20.59 | 20.37 | 21.25 | 19.68 | 19.83 | 19.74 | 19.78 |
| Mt | 1.10 | 0.83 | 0.61 | 1.62 | 1.74 | 2.22 | 1.41 |
| Il | 1.22 | 1.16 | 1.22 | 1.20 | 1.20 | 1.25 | 1.20 |
| Ap | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.23 | 0.21 |
| rest | 1.51 | 1.12 | 0.81 | 1.38 | 1.26 | 1.49 | 1.07 |
| Total | 100.22 | 99.75 | 100.32 | 99.49 | 100.59 | 100.02 | 100.16 |
| | | | | | | | |
| Mg# | 61.4 | 61.0 | 60.8 | 61.0 | 61.5 | 58.9 | 61.2 |

| | **84 128** | **84 129** | **84 138** | **84 140** | **84 141** | **84 143** | **84 144** |
|---|---|---|---|---|---|---|---|
| $\mathrm{Cs}_{\mathrm{INAA}}$ | 3.77 | 4.96 | 1.01 | 1.02 | 1.27 | 1.68 | 1.08 |
| Ba | 190 | 180 | 190 | 195 | 310 | 235 | 200 |
| $\mathrm{Ba}_{\mathrm{INAA}}$ | 178 | 184 | 181 | 171 | 264 | 239 | 178 |
| Rb | 25.4 | 26.4 | 31.7 | 29.8 | 30.0 | 35.6 | 34.6 |
| $\mathrm{Rb}_{\mathrm{INAA}}$ | 23 | 24 | 28 | 27 | 29 | 33 | 25 |
| $\mathrm{Rb}_{\mathrm{ID}}$ | | 26.3 | 31.2 | | 31.5 | | 32.8 |
| Sr | 121.2 | 122.1 | 123.9 | 125.8 | 115.8 | 123.8 | 119.3 |
| $\mathrm{Sr}_{\mathrm{ID}}$ | | 119.3 | 121.0 | | 114.7 | | 111.1 |
| Pb | 6 | 5 | 6 | 5 | 6 | 6 | 6 |
| La | 12 | 11 | 10 | 11 | 12 | 11 | 12 |
| $\mathrm{La}_{\mathrm{INAA}}$ | 10.9 | 10.6 | 11.0 | 10.9 | 11.0 | 11.4 | 10.6 |
| Ce | 25 | 24 | 25 | 24 | 26 | 27 | 23 |
| $\mathrm{Ce}_{\mathrm{INAA}}$ | 23.6 | 24.0 | 23.9 | 24.2 | 24.1 | 25.9 | 24.2 |
| $\mathrm{Nd}_{\mathrm{INAA}}$ | 11.7 | 12.6 | 11.9 | 12.5 | 12.0 | 13.1 | 12.6 |
| $\mathrm{Nd}_{\mathrm{ID}}$ | | 12.38 | 12.56 | | 12.13 | | 12.55 |
| $\mathrm{Sm}_{\mathrm{INAA}}$ | 3.05 | 3.07 | 3.09 | 3.10 | 3.02 | 3.19 | 3.04 |
| $\mathrm{Sm}_{\mathrm{ID}}$ | | 2.91 | 2.96 | | 3.05 | | 2.96 |
| $\mathrm{Eu}_{\mathrm{INAA}}$ | 0.813 | 0.803 | 0.822 | 0.829 | 0.825 | 0.878 | 0.817 |
| $\mathrm{Gd}_{\mathrm{INAA}}$ | 3.1 | 2.9 | 3.0 | 3.0 | 3.1 | 3.3 | 3.0 |
| $\mathrm{Tb}_{\mathrm{INAA}}$ | 0.56 | 0.55 | 0.57 | 0.60 | 0.58 | 0.59 | 0.55 |
| $\mathrm{Ho}_{\mathrm{INAA}}$ | 0.78 | 0.77 | 0.83 | 0.76 | 0.80 | 0.80 | 0.86 |
| $\mathrm{Yb}_{\mathrm{INAA}}$ | 2.34 | 2.41 | 2.37 | 2.38 | 2.37 | 2.42 | 2.26 |
| $\mathrm{Lu}_{\mathrm{INAA}}$ | 0.356 | 0.354 | 0.366 | 0.367 | 0.359 | 0.387 | 0.361 |
| Y | 20.1 | 19.8 | 20.6 | 19.9 | 19.7 | 21.6 | 20.1 |
| Th | 3 | 4 | 5 | 5 | 3 | 4 | 5 |
| $\mathrm{Th}_{\mathrm{INAA}}$ | 3.5 | 3.4 | 3.4 | 3.5 | 3.3 | 3.8 | 3.4 |
| $\mathrm{U}_{\mathrm{INAA}}$ | 0.9 | 1.1 | 1.1 | 1.1 | 1.0 | 1.3 | 0.9 |
| Zr | 94 | 94 | 95 | 94 | 93 | 102 | 91 |
| $\mathrm{Hf}_{\mathrm{INAA}}$ | 1.8 | 1.9 | 1.9 | 1.9 | 1.9 | 2.0 | 1.8 |
| Nb | 4.5 | 4.5 | 4.0 | 4.5 | 4.0 | 5.5 | 4.5 |
| $\mathrm{Sc}_{\mathrm{INAA}}$ | 40.7 | 40.6 | 41.2 | 40.9 | 41.4 | 42.6 | 41.3 |
| V | 219 | 212 | 223 | 214 | 214 | 232 | 220 |
| Cr | 116 | 113 | 115 | 107 | 107 | 78 | 115 |
| $\mathrm{Cr}_{\mathrm{INAA}}$ | 121 | 119 | 122 | 120 | 121 | 83 | 121 |
| Mn | 1340 | 1310 | 1330 | 1290 | 1290 | 1390 | 1320 |
| Co | 47 | 49 | 49 | 48 | 47 | 52 | 48 |
| Ni | 79 | 78 | 80 | 78 | 75 | 71 | 79 |
| Cu | 80 | 64 | 76 | 76 | 72 | 80 | 62 |
| Zn | 79 | 78 | 78 | 80 | 75 | 85 | 76 |
| Ga | 16.0 | 16.5 | 16.5 | 16.5 | 16.5 | 17.5 | 15.0 |

| | **84 147** | **84 148** | **84 149** | **84 150** | **84 152** | **84 167** | **84 167b** |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 54.22 | 54.65 | 53.79 | 54.17 | 54.30 | 54.19 | 54.19 |
| $TiO_2$ | 0.63 | 0.64 | 0.63 | 0.63 | 0.64 | 0.63 | 0.64 |
| $Al_2O_3$ | 14.65 | 14.86 | 14.61 | 14.63 | 14.62 | 14.74 | 14.67 |
| $Fe_2O_3$ | 0.71 | 0.32 | 0.65 | 0.95 | 1.65 | 0.61 | 0.75 |
| FeO | 8.13 | 8.52 | 8.15 | 7.90 | 7.29 | 8.30 | 8.12 |
| MnO | 0.17 | 0.17 | 0.18 | 0.17 | 0.17 | 0.18 | 0.17 |
| MgO | 6.64 | 6.77 | 6.64 | 6.75 | 6.60 | 6.68 | 6.62 |
| CaO | 10.87 | 10.95 | 10.93 | 10.92 | 10.92 | 10.89 | 10.92 |
| $CaO_{INAA}$ | 11.2 | 10.9 | 10.9 | 10.8 | 10.9 | 11.1 | 10.0 |
| $Na_2O$ | 1.86 | 1.81 | 1.76 | 1.85 | 1.68 | 1.94 | 1.83 |
| $Na_2O_{INAA}$ | 1.97 | 1.76 | 1.75 | 1.75 | 1.58 | 1.83 | 1.68 |
| $K_2O$ | 0.81 | 0.85 | 0.83 | 0.84 | 0.85 | 0.66 | 0.75 |
| $P_2O_5$ | 0.09 | 0.10 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 |
| S | 0.05 | 0.11 | 0.05 | 0.05 | 0.05 | 0.04 | 0.04 |
| $H_2O$ + | 0.44 | 0.39 | 0.61 | 0.67 | 0.78 | 0.57 | 0.45 |
| $H_2O$ - | 0.29 | 0.23 | 0.35 | 0.38 | 0.32 | 0.24 | 0.29 |
| $CO_2$ | 0.16 | 0.29 | 0.19 | 0.21 | 0.12 | 0.20 | 0.11 |
| rest | 0.14 | 0.15 | 0.15 | 0.15 | 0.15 | 0.14 | 0.14 |
| | 99.86 | 100.81 | 99.61 | 100.36 | 100.23 | 100.10 | 99.78 |
| O=S | 0.02 | 0.05 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| Total | 99.84 | 100.76 | 99.59 | 100.34 | 100.21 | 100.08 | 99.76 |
| Q | 6.37 | 6.06 | 6.27 | 6.35 | 8.28 | 6.11 | 6.67 |
| Or | 4.79 | 5.02 | 4.91 | 4.96 | 5.02 | 3.90 | 4.43 |
| Ab | 15.74 | 15.32 | 14.89 | 15.65 | 14.22 | 16.42 | 15.48 |
| An | 29.23 | 29.91 | 29.51 | 29.13 | 29.84 | 29.56 | 29.60 |
| Di | 19.82 | 19.56 | 19.84 | 20.06 | 19.41 | 19.64 | 19.72 |
| Hy | 20.41 | 21.86 | 20.50 | 19.96 | 18.23 | 21.00 | 20.34 |
| Mt | 1.03 | 0.46 | 0.94 | 1.38 | 2.39 | 0.88 | 1.09 |
| Il | 1.20 | 1.22 | 1.20 | 1.20 | 1.22 | 1.20 | 1.22 |
| Ap | 0.21 | 0.23 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 |
| rest | 0.89 | 0.91 | 1.15 | 1.26 | 1.22 | 1.01 | 0.85 |
| Total | 99.69 | 100.55 | 99.42 | 100.16 | 100.04 | 99.93 | 99.61 |
| Mg# | 60.8 | 61.2 | 60.9 | 61.2 | 60.7 | 60.7 | 60.7 |

| | **84 147** | **84 148** | **84 149** | **84 150** | **84 152** | **84 167** | **84 167b** |
|---|---|---|---|---|---|---|---|
| Cs$_{\mathrm{INAA}}$ | 1.18 | 0.98 | 0.95 | 0.92 | 1.34 | 1.06 | 0.92 |
| Ba | 190 | 200 | 190 | 190 | 250 | 190 | 190 |
| Ba$_{\mathrm{INAA}}$ | 185 | 198 | 185 | 200 | 235 | 199 | 176 |
| Rb | 30.5 | 30.2 | 30.4 | 29.7 | 29.9 | 28.0 | 32.5 |
| Rb$_{\mathrm{INAA}}$ | 26 | 24 | 22 | 25 | 25 | 24 | 28 |
| Rb$_{\mathrm{ID}}$ | | | 34.0 | | 30.0 | | 32.4 |
| Sr | 120.3 | 123.7 | 128.6 | 128.5 | 123.6 | 115.7 | 115.1 |
| Sr$_{\mathrm{ID}}$ | | | 131.9 | | 123.9 | | 114.6 |
| Pb | 5 | 6 | 5 | 6 | 5 | 6 | 5 |
| La | 11 | 12 | 11 | 12 | 11 | 11 | 11 |
| La$_{\mathrm{INAA}}$ | 10.9 | 10.8 | 10.8 | 10.9 | 10.8 | 10.5 | 10.3 |
| Ce | 25 | 24 | 26 | 24 | 26 | 27 | 24 |
| Ce$_{\mathrm{INAA}}$ | 24.3 | 24.5 | 24.0 | 24.5 | 24.7 | 24.4 | 23.0 |
| Nd$_{\mathrm{INAA}}$ | 12.4 | 11.8 | 12.6 | 12.5 | 12.6 | 12.2 | 12.3 |
| Nd$_{\mathrm{ID}}$ | | | 12.71 | | 13.96 | | 12.63 |
| Sm$_{\mathrm{INAA}}$ | 3.01 | 3.04 | 3.09 | 3.05 | 3.07 | 3.04 | 2.87 |
| Sm$_{\mathrm{ID}}$ | | | 3.02 | | 3.30 | | 2.97 |
| Eu$_{\mathrm{INAA}}$ | 0.815 | 0.824 | 0.831 | 0.825 | 0.819 | 0.830 | 0.783 |
| Gd$_{\mathrm{INAA}}$ | 3.0 | 3.1 | 3.2 | 3.2 | 3.2 | 3.1 | 2.9 |
| Tb$_{\mathrm{INAA}}$ | 0.57 | 0.58 | 0.55 | 0.55 | 0.58 | 0.58 | 0.56 |
| Ho$_{\mathrm{INAA}}$ | 0.65 | 0.87 | 0.90 | 0.90 | 0.83 | 0.80 | 0.83 |
| Yb$_{\mathrm{INAA}}$ | 2.34 | 2.35 | 2.31 | 2.29 | 2.33 | 2.20 | 2.20 |
| Lu$_{\mathrm{INAA}}$ | 0.361 | 0.363 | 0.362 | 0.353 | 0.361 | 0.368 | 0.335 |
| Y | 19.9 | 20.2 | 20.9 | 19.9 | 20.7 | 20.2 | 19.8 |
| Th | 3 | 4 | 4 | 4 | 4 | 3 | 3 |
| Th$_{\mathrm{INAA}}$ | 3.3 | 3.3 | 3.4 | 3.4 | 3.6 | 3.6 | 3.7 |
| U$_{\mathrm{INAA}}$ | 0.9 | 0.9 | 0.9 | 1.0 | 1.2 | 1.3 | 1.0 |
| Zr | 93 | 95 | 94 | 92 | 95 | 93 | 93 |
| Hf$_{\mathrm{INAA}}$ | 1.9 | 1.9 | 1.7 | 1.9 | 1.9 | 1.9 | 1.8 |
| Nb | 4.5 | 4.5 | 4.0 | 5.0 | 4.5 | 5.0 | 4.0 |
| Sc$_{\mathrm{INAA}}$ | 40.9 | 41.5 | 40.9 | 41.1 | 40.7 | 41.1 | 38.8 |
| V | 220 | 224 | 223 | 223 | 218 | 227 | 221 |
| Cr | 113 | 117 | 117 | 115 | 111 | 116 | 114 |
| Cr$_{\mathrm{INAA}}$ | 118 | 121 | 120 | 120 | 120 | 119 | 112 |
| Mn | 1330 | 1340 | 1370 | 1330 | 1310 | 1380 | 1340 |
| Co | 49 | 51 | 51 | 50 | 48 | 51 | 48 |
| Ni | 79 | 80 | 79 | 79 | 76 | 80 | 78 |
| Cu | 65 | 77 | 65 | 71 | 75 | 64 | 70 |
| Zn | 77 | 77 | 79 | 77 | 76 | 80 | 77 |
| Ga | 16.0 | 17.0 | 16.5 | 16.0 | 16.5 | 15.5 | 16.5 |

| | **84 168** | **84 169** | **84 170** | **84 196** | **84 199** | **84 200** | **84 203** |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 51.04 | 53.70 | 53.91 | 53.99 | 54.54 | 54.51 | 54.44 |
| $TiO_2$ | 0.64 | 0.62 | 0.62 | 0.64 | 0.63 | 0.63 | 0.63 |
| $Al_2O_3$ | 15.06 | 14.50 | 14.57 | 14.62 | 14.78 | 14.69 | 14.70 |
| $Fe_2O_3$ | 2.70 | 1.80 | 1.72 | 1.71 | 1.24 | 0.91 | 0.92 |
| FeO | 5.36 | 7.01 | 7.17 | 7.10 | 7.61 | 8.00 | 7.96 |
| MnO | 0.27 | 0.18 | 0.18 | 0.17 | 0.18 | 0.17 | 0.18 |
| MgO | 5.29 | 6.88 | 6.89 | 6.68 | 6.79 | 6.77 | 6.63 |
| CaO | 12.15 | 9.94 | 9.67 | 10.20 | 10.55 | 10.61 | 10.83 |
| $CaO_{INAA}$ | 12.2 | 9.7 | 9.8 | 10.7 | 10.8 | 10.4 | 6.5 |
| $Na_2O$ | 1.74 | 2.01 | 2.20 | 2.10 | 2.20 | 1.95 | 1.68 |
| $Na_2O_{INAA}$ | 1.71 | 1.91 | 2.06 | 1.87 | 2.03 | 1.84 | 1.58 |
| $K_2O$ | 0.81 | 1.01 | 1.18 | 0.93 | 0.83 | 0.98 | 0.90 |
| $P_2O_5$ | 0.10 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 |
| S | 0.05 | 0.05 | 0.04 | 0.04 | 0.05 | 0.04 | 0.04 |
| $H_2O$ + | 1.75 | 1.53 | 1.40 | 1.07 | 0.65 | 0.71 | 0.45 |
| $H_2O$ - | 1.25 | 0.49 | 0.50 | 0.52 | 0.28 | 0.28 | 0.41 |
| $CO_2$ | 2.31 | 0.29 | 0.15 | 0.10 | 0.13 | 0.13 | 0.08 |
| rest | 0.18 | 0.21 | 0.29 | 0.16 | 0.15 | 0.15 | 0.15 |
| | 100.70 | 100.31 | 100.58 | 100.12 | 100.70 | 100.62 | 100.09 |
| O=S | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| Total | 100.68 | 100.29 | 100.56 | 100.10 | 100.68 | 100.60 | 100.07 |
| | | | | | | | |
| Q | 7.17 | 6.54 | 5.36 | 6.51 | 5.64 | 5.92 | 7.41 |
| Or | 4.79 | 5.97 | 6.97 | 5.50 | 4.91 | 5.79 | 5.32 |
| Ab | 14.72 | 17.01 | 18.62 | 17.77 | 18.62 | 16.50 | 14.22 |
| An | 30.89 | 27.56 | 26.40 | 27.72 | 28.00 | 28.44 | 29.91 |
| Di | 23.31 | 17.25 | 17.12 | 18.19 | 19.44 | 19.38 | 19.07 |
| Hy | 8.92 | 19.42 | 19.86 | 18.64 | 19.63 | 20.56 | 20.29 |
| Mt | 3.91 | 2.61 | 2.49 | 2.48 | 1.80 | 1.32 | 1.33 |
| Il | 1.22 | 1.18 | 1.18 | 1.22 | 1.20 | 1.20 | 1.20 |
| Ap | 0.23 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 |
| rest | 5.31 | 2.31 | 2.05 | 1.69 | 1.06 | 1.12 | 0.94 |
| Total | 100.47 | 100.06 | 100.26 | 99.93 | 100.51 | 100.44 | 99.90 |
| | | | | | | | |
| Mg# | 58.2 | 62.0 | 61.8 | 61.3 | 61.5 | 61.1 | 60.7 |

| | **84 168** | **84 169** | **84 170** | **84 196** | **84 199** | **84 200** | **84 203** |
|---|---|---|---|---|---|---|---|
| $Cs_{INAA}$ | 1.17 | 2.14 | 2.62 | 2.96 | 1.94 | 1.28 | 0.74 |
| Ba | 460 | 785 | 1400 | 270 | 210 | 220 | 220 |
| $Ba_{INAA}$ | 408 | 685 | 1198 | 258 | 175 | 194 | 203 |
| Rb | 29.3 | 38.8 | 44.5 | 36.2 | 31.1 | 37.6 | 35.4 |
| $Rb_{INAA}$ | 24 | 29 | 37 | 31 | 28 | 30 | 29 |
| $Rb_{ID}$ | 29.8 | 38.8 | 44.1 | 35.4 | | | 35.0 |
| Sr | 146.4 | 137.7 | 167.8 | 151.5 | 130.4 | 134.8 | 119.5 |
| $Sr_{ID}$ | 146.5 | 136.9 | 164.3 | 153.5 | | | 115.5 |
| Pb | 5 | 5 | 6 | 6 | 5 | 6 | 6 |
| La | 12 | 11 | 12 | 12 | 11 | 11 | 12 |
| $La_{INAA}$ | 11.2 | 10.5 | 10.8 | 10.6 | 10.9 | 10.9 | 10.8 |
| Ce | 26 | 26 | 28 | 25 | 24 | 26 | 25 |
| $Ce_{INAA}$ | 24.4 | 23.2 | 24.2 | 24.6 | 24.1 | 24.2 | 24.4 |
| $Nd_{INAA}$ | 12.9 | 12.0 | 12.6 | 12.6 | 11.9 | 12.6 | 12.3 |
| $Nd_{ID}$ | 12.82 | 12.23 | 12.44 | 12.47 | | | 12.46 |
| $Sm_{INAA}$ | 3.11 | 2.92 | 3.03 | 3.09 | 3.02 | 3.05 | 3.12 |
| $Sm_{ID}$ | 3.05 | 2.89 | 2.93 | 2.96 | | | 2.94 |
| $Eu_{INAA}$ | 0.884 | 0.792 | 0.814 | 0.833 | 0.815 | 0.832 | 0.819 |
| $Gd_{INAA}$ | 3.4 | 3.0 | 3.1 | 3.0 | 3.3 | 3.2 | 3.0 |
| $Tb_{INAA}$ | 0.57 | 0.53 | 0.55 | 0.55 | 0.56 | 0.53 | 0.56 |
| $Ho_{INAA}$ | 0.88 | 0.78 | 0.81 | 0.81 | 0.77 | 0.81 | 0.78 |
| $Yb_{INAA}$ | 2.40 | 2.20 | 2.22 | 2.26 | 2.32 | 2.35 | 2.34 |
| $Lu_{INAA}$ | 0.377 | 0.352 | 0.362 | 0.366 | 0.357 | 0.355 | 0.359 |
| Y | 21.6 | 19.6 | 20.0 | 20.7 | 20.2 | 20.0 | 20.3 |
| Th | 5 | 4 | 5 | 1 | 3 | 6 | 2 |
| $Th_{INAA}$ | 3.4 | 3.2 | 3.4 | 3.3 | 3.3 | 3.3 | 3.5 |
| $U_{INAA}$ | 0.8 | 1.0 | 0.8 | 0.9 | 0.9 | 1.0 | 1.0 |
| Zr | 95 | 90 | 88 | 95 | 94 | 93 | 93 |
| $Hf_{INAA}$ | 1.9 | 1.8 | 1.9 | 2.0 | 1.9 | 1.8 | 1.9 |
| Nb | 4.5 | 4.5 | 4.5 | 4.0 | 4.0 | 4.5 | 4.0 |
| $Sc_{INAA}$ | 42.4 | 40.9 | 41.4 | 40.8 | 41.0 | 41.6 | 41.3 |
| V | 239 | 226 | 220 | 220 | 233 | 219 | 231 |
| Cr | 122 | 117 | 115 | 110 | 115 | 109 | 114 |
| $Cr_{INAA}$ | 123 | 119 | 120 | 118 | 121 | 116 | 116 |
| Mn | 2110 | 1420 | 1400 | 1300 | 1370 | 1320 | 1380 |
| Co | 50 | 50 | 49 | 49 | 51 | 48 | 49 |
| Ni | 82 | 79 | 79 | 78 | 81 | 78 | 78 |
| Cu | 74 | 72 | 76 | 74 | 77 | 76 | 78 |
| Zn | 81 | 77 | 79 | 81 | 79 | 77 | 78 |
| Ga | 16.0 | 15.0 | 16.5 | 16.5 | 16.5 | 16.5 | 15.5 |

| | **84 205** | **84 206** | **84 213** | **84 214** | **84 221** | **84 222** | **84 301** |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 53.94 | 53.85 | 54.86 | 55.05 | 53.41 | 52.89 | 54.08 |
| $TiO_2$ | 0.64 | 0.63 | 0.68 | 0.67 | 0.62 | 0.64 | 0.63 |
| $Al_2O_3$ | 14.86 | 14.61 | 14.60 | 14.49 | 14.69 | 14.68 | 14.64 |
| $Fe_2O_3$ | 2.08 | 0.82 | 0.80 | 0.61 | 1.73 | 1.81 | 2.44 |
| FeO | 6.66 | 7.94 | 8.35 | 8.56 | 7.09 | 7.28 | 6.55 |
| MnO | 0.17 | 0.18 | 0.19 | 0.18 | 0.18 | 0.18 | 0.17 |
| MgO | 6.13 | 6.63 | 6.08 | 6.21 | 6.76 | 6.49 | 6.48 |
| CaO | 10.27 | 10.85 | 10.40 | 10.38 | 9.58 | 10.16 | 10.26 |
| $CaO_{INAA}$ | 10.0 | 10.7 | 10.3 | 10.3 | 9.8 | 10.4 | 10.2 |
| $Na_2O$ | 1.92 | 1.91 | 1.92 | 2.03 | 2.50 | 2.45 | 1.76 |
| $Na_2O_{INAA}$ | 1.81 | 1.73 | 1.80 | 1.86 | 2.35 | 2.29 | 1.65 |
| $K_2O$ | 0.88 | 0.89 | 0.76 | 1.05 | 1.09 | 1.01 | 0.86 |
| $P_2O_5$ | 0.09 | 0.10 | 0.11 | 0.11 | 0.09 | 0.09 | 0.09 |
| S | 0.03 | 0.05 | 0.07 | 0.05 | 0.02 | 0.02 | 0.03 |
| $H_2O +$ | 1.08 | 1.04 | 0.99 | 0.55 | 2.11 | 2.24 | 1.20 |
| $H_2O -$ | 1.10 | 0.41 | 0.29 | 0.20 | 0.56 | 0.73 | 0.85 |
| $CO_2$ | 0.04 | 0.41 | 0.11 | 0.07 | 0.14 | 0.12 | 0.25 |
| rest | 0.15 | 0.15 | 0.14 | 0.15 | 0.16 | 0.16 | 0.15 |
| | 100.04 | 100.47 | 100.35 | 100.36 | 100.73 | 100.95 | 100.44 |
| O=S | 0.01 | 0.02 | 0.03 | 0.02 | 0.01 | 0.01 | 0.01 |
| Total | 100.03 | 100.45 | 100.32 | 100.34 | 100.72 | 100.94 | 100.43 |
| | | | | | | | |
| Q | 8.61 | 5.77 | 8.14 | 6.52 | 3.98 | 3.63 | 9.42 |
| Or | 5.20 | 5.26 | 4.49 | 6.21 | 6.44 | 5.97 | 5.08 |
| Ab | 16.25 | 16.16 | 16.25 | 17.18 | 21.15 | 20.73 | 14.89 |
| An | 29.33 | 28.66 | 28.97 | 27.32 | 25.64 | 26.08 | 29.51 |
| Di | 17.15 | 20.13 | 18.07 | 19.36 | 17.37 | 19.41 | 16.91 |
| Hy | 16.67 | 19.82 | 20.12 | 20.34 | 19.26 | 17.82 | 17.20 |
| Mt | 3.02 | 1.19 | 1.16 | 0.88 | 2.51 | 2.62 | 3.54 |
| Il | 1.22 | 1.20 | 1.29 | 1.27 | 1.18 | 1.22 | 1.20 |
| Ap | 0.21 | 0.23 | 0.26 | 0.26 | 0.21 | 0.21 | 0.21 |
| rest | 2.22 | 1.86 | 1.39 | 0.82 | 2.81 | 3.09 | 2.30 |
| Total | 99.88 | 100.28 | 100.14 | 100.16 | 100.55 | 100.78 | 100.26 |
| | | | | | | | |
| Mg# | 59.6 | 61.0 | 57.9 | 58.3 | 61.6 | 59.9 | 60.3 |

| | **84 205** | **84 206** | **84 213** | **84 214** | **84 221** | **84 222** | **84 301** |
|---|---|---|---|---|---|---|---|
| $\mathrm{Cs_{INAA}}$ | 0.98 | 1.57 | 1.67 | 1.69 | 1.83 | 1.18 | 1.01 |
| Ba | 215 | 205 | 175 | 245 | 235 | 255 | 230 |
| $\mathrm{Ba_{INAA}}$ | 189 | 166 | 167 | 233 | 212 | 235 | 199 |
| Rb | 31.8 | 34.4 | 27.9 | 40.0 | 42.9 | 37.6 | 30.7 |
| $\mathrm{Rb_{INAA}}$ | 26 | 25 | 27 | 35 | 35 | 31 | 27 |
| $\mathrm{Rb_{ID}}$ | 32.4 | | | | 42.1 | 38.7 | 31.5 |
| Sr | 123.0 | 125.0 | 130.8 | 143.8 | 204.6 | 185.6 | 150.3 |
| $\mathrm{Sr_{ID}}$ | 125.0 | | | | 199.2 | 190.3 | 153.3 |
| Pb | 12 | 7 | 6 | 7 | 5 | 5 | 6 |
| La | 11 | 11 | 12 | 12 | 11 | 11 | 11 |
| $\mathrm{La_{INAA}}$ | 10.6 | 10.7 | 11.5 | 11.5 | 10.7 | 11.1 | 11.1 |
| Ce | 26 | 22 | 26 | 23 | 24 | 22 | 26 |
| $\mathrm{Ce_{INAA}}$ | 24.5 | 22.6 | 25.5 | 26.4 | 24.2 | 25.9 | 25.0 |
| $\mathrm{Nd_{INAA}}$ | 12.6 | 11.6 | 13.7 | 13.4 | 12.7 | 13.2 | 12.6 |
| $\mathrm{Nd_{ID}}$ | 12.62 | | | | 12.28 | 12.73 | 12.73 |
| $\mathrm{Sm_{INAA}}$ | 3.12 | 3.01 | 3.31 | 3.26 | 2.96 | 3.11 | 3.08 |
| $\mathrm{Sm_{ID}}$ | 3.00 | | | | 2.17 | 3.00 | 2.99 |
| $\mathrm{Eu_{INAA}}$ | 0.844 | 0.799 | 0.867 | 0.885 | 0.823 | 0.866 | 0.848 |
| $\mathrm{Gd_{INAA}}$ | 3.2 | 3.1 | 3.1 | 2.3 | 3.0 | 3.1 | 3.1 |
| $\mathrm{Tb_{INAA}}$ | 0.56 | 0.52 | 0.63 | 0.60 | 0.59 | 0.60 | 0.57 |
| $\mathrm{Ho_{INAA}}$ | 0.94 | 0.72 | 0.93 | 0.87 | 0.79 | 0.90 | 0.79 |
| $\mathrm{Yb_{INAA}}$ | 2.43 | 2.31 | 2.46 | 2.52 | 2.28 | 2.38 | 2.48 |
| $\mathrm{Lu_{INAA}}$ | 0.384 | 0.336 | 0.379 | 0.383 | 0.356 | 0.372 | 0.366 |
| Y | 21.1 | 20.1 | 21.2 | 21.0 | 19.8 | 20.5 | 20.2 |
| Th | 3 | 3 | 3 | 5 | 5 | 5 | 4 |
| $\mathrm{Th_{INAA}}$ | 3.5 | 3.3 | 3.8 | 3.7 | 3.4 | 3.8 | 3.6 |
| $\mathrm{U_{INAA}}$ | 1.1 | 1.4 | 1.0 | 1.4 | 1.1 | 0.8 | 1.6 |
| Zr | 96 | 93 | 100 | 101 | 94 | 95 | 97 |
| $\mathrm{Hf_{INAA}}$ | 1.9 | 1.7 | 2.1 | 2.2 | 1.9 | 2.0 | 1.9 |
| Nb | 5.0 | 4.5 | 5.0 | 4.5 | 4.0 | 4.0 | 4.5 |
| $\mathrm{Sc_{INAA}}$ | 42.2 | 40.6 | 43.1 | 43.0 | 41.0 | 42.0 | 41.3 |
| V | 232 | 224 | 235 | 235 | 225 | 232 | 227 |
| Cr | 108 | 114 | 80 | 76 | 116 | 118 | 107 |
| $\mathrm{Cr_{INAA}}$ | 115 | 117 | 83 | 80 | 119 | 120 | 111 |
| Mn | 1240 | 1370 | 1480 | 1380 | 1370 | 1360 | 1320 |
| Co | 49 | 48 | 48 | 49 | 51 | 50 | 49 |
| Ni | 83 | 79 | 70 | 69 | 79 | 81 | 76 |
| Cu | 77 | 76 | 76 | 74 | 72 | 75 | 75 |
| Zn | 98 | 81 | 79 | 78 | 79 | 81 | 77 |
| Ga | 17.0 | 16.0 | 16.5 | 17.0 | 16.5 | 17.0 | 16.5 |

| | **84 323** | **84 324** |
|---|---|---|
| $SiO_2$ | 55.17 | 54.87 |
| $TiO_2$ | 0.67 | 0.66 |
| $Al_2O_3$ | 14.48 | 14.41 |
| $Fe_2O_3$ | 1.19 | 1.15 |
| FeO | 7.81 | 7.71 |
| MnO | 0.17 | 0.17 |
| MgO | 6.26 | 6.16 |
| CaO | 10.44 | 10.29 |
| $CaO_{INAA}$ | 10.5 | 10.2 |
| $Na_2O$ | 1.87 | 1.81 |
| $Na_2O_{INAA}$ | 1.78 | 1.76 |
| $K_2O$ | 0.92 | 0.88 |
| $P_2O_5$ | 0.10 | 0.10 |
| S | 0.05 | 0.05 |
| $H_2O$ + | 0.78 | 0.91 |
| $H_2O$ - | 0.25 | 0.40 |
| $CO_2$ | 0.26 | 0.66 |
| rest | 0.15 | 0.15 |
| | 100.57 | 100.38 |
| O=S | 0.02 | 0.02 |
| Total | 100.55 | 100.36 |
| | | |
| Q | 8.54 | 9.07 |
| Or | 5.44 | 5.20 |
| Ab | 15.82 | 15.32 |
| An | 28.40 | 28.60 |
| Di | 18.68 | 17.91 |
| Hy | 18.97 | 18.97 |
| Mt | 1.73 | 1.67 |
| Il | 1.27 | 1.25 |
| Ap | 0.23 | 0.23 |
| rest | 1.29 | 1.97 |
| Total | 100.37 | 100.19 |
| | | |
| Mg# | 59.1 | 59.1 |

| | 84 323 | 84 324 |
|---|---|---|
| $Cs_{INAA}$ | 1.71 | 2.16 |
| Ba | 230 | 235 |
| $Ba_{INAA}$ | 205 | 209 |
| Rb | 32.7 | 32.4 |
| $Rb_{INAA}$ | 28 | 28 |
| $Rb_{ID}$ | | |
| Sr | 128.9 | 129.2 |
| $Sr_{ID}$ | | |
| Pb | 6 | 6 |
| La | 11 | 11 |
| $La_{INAA}$ | 11.2 | 11.1 |
| Ce | 27 | 25 |
| $Ce_{INAA}$ | 26.4 | 26.3 |
| $Nd_{INAA}$ | 13.1 | 13.6 |
| $Nd_{ID}$ | | |
| $Sm_{INAA}$ | 3.27 | 3.16 |
| $Sm_{ID}$ | | |
| $Eu_{INAA}$ | 0.882 | 0.882 |
| $Gd_{INAA}$ | 3.4 | 3.4 |
| $Tb_{INAA}$ | 0.64 | 0.63 |
| $Ho_{INAA}$ | 0.92 | 0.96 |
| $Yb_{INAA}$ | 2.46 | 2.45 |
| $Lu_{INAA}$ | 0.377 | 0.379 |
| Y | 20.4 | 20.8 |
| Th | 6 | 5 |
| $Th_{INAA}$ | 3.5 | 3.5 |
| $U_{INAA}$ | 1.0 | 1.0 |
| Zr | 101 | 101 |
| $Hf_{INAA}$ | 2.1 | 2.2 |
| Nb | 4.5 | 4.5 |
| $Sc_{INAA}$ | 43.1 | 42.8 |
| V | 235 | 233 |
| Cr | 80 | 79 |
| $Cr_{INAA}$ | 85 | 84 |
| Mn | 1290 | 1280 |
| Co | 48 | 49 |
| Ni | 71 | 68 |
| Cu | 72 | 73 |
| Zn | 79 | 80 |
| Ga | 17.0 | 17.0 |

# XRF, INAA AND WET CHEMICAL ANALYSES OF DIFFERENTIATED DOLERITES

| | **84 103** | **84 104** | **84 127** | **84 132** | **84 133** | **84 134** | **84 153** |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 62.91 | 67.29 | 54.19 | 54.63 | 55.10 | 56.78 | 54.06 |
| $TiO_2$ | 1.26 | 0.83 | 0.75 | 0.94 | 1.57 | 1.59 | 0.62 |
| $Al_2O_3$ | 10.86 | 11.09 | 17.64 | 16.99 | 14.83 | 14.39 | 14.52 |
| $Fe_2O_3$ | 5.90 | 3.51 | 1.52 | 1.99 | 3.52 | 4.17 | 1.25 |
| FeO | 6.22 | 5.32 | 7.24 | 7.93 | 8.77 | 7.91 | 7.62 |
| MnO | 0.18 | 0.14 | 0.14 | 0.14 | 0.16 | 0.15 | 0.17 |
| MgO | 0.53 | 0.20 | 3.10 | 2.52 | 2.09 | 1.43 | 6.68 |
| CaO | 4.54 | 3.60 | 10.25 | 9.45 | 7.95 | 7.14 | 10.64 |
| $Na_2O$ | 2.59 | 2.89 | 2.29 | 2.45 | 2.69 | 2.72 | 1.77 |
| $Na_2O_{INAA}$ | 2.47 | 2.70 | 2.16 | 2.33 | 2.31 | 2.49 | 1.66 |
| $K_2O$ | 2.67 | 3.08 | 1.05 | 1.13 | 1.40 | 1.65 | 0.92 |
| $P_2O_5$ | 0.38 | 0.19 | 0.11 | 0.12 | 0.15 | 0.18 | 0.09 |
| S | 0.06 | 0.05 | 0.03 | 0.05 | 0.07 | 0.05 | 0.05 |
| $H_2O+$ | 1.18 | 0.97 | 1.62 | 1.18 | 1.20 | 1.43 | 0.75 |
| $H_2O-$ | 0.47 | 0.70 | 0.26 | 0.22 | 0.34 | 0.38 | 0.31 |
| $CO_2$ | 0.46 | 0.18 | 0.12 | 0.17 | 0.16 | 0.16 | 0.13 |
| rest | 0.18 | 0.19 | 0.14 | 0.15 | 0.19 | 0.16 | 0.15 |
| | 100.39 | 100.23 | 100.45 | 100.06 | 100.19 | 100.29 | 99.73 |
| O=S | 0.03 | 0.02 | 0.01 | 0.02 | 0.03 | 0.02 | 0.02 |
| Total | 100.36 | 100.21 | 100.44 | 100.04 | 100.16 | 100.27 | 99.71 |
| | | | | | | | |
| Q | 28.14 | 30.41 | 8.86 | 10.13 | 12.47 | 16.35 | 7.18 |
| Or | 15.78 | 18.20 | 6.21 | 6.68 | 8.27 | 9.75 | 5.44 |
| Ab | 21.92 | 24.45 | 19.38 | 20.73 | 22.76 | 23.02 | 14.98 |
| An | 10.12 | 8.19 | 34.75 | 32.02 | 24.26 | 22.18 | 28.96 |
| Di | 8.55 | 7.42 | 12.88 | 11.89 | 12.05 | 10.28 | 19.04 |
| Hy | 1.72 | 2.36 | 12.32 | 11.89 | 9.99 | 7.05 | 19.56 |
| Mt | 8.55 | 5.09 | 2.20 | 2.89 | 5.10 | 6.05 | 1.81 |
| Il | 2.39 | 1.58 | 1.42 | 1.79 | 2.98 | 3.02 | 1.18 |
| Ap | 0.88 | 0.44 | 0.26 | 0.28 | 0.35 | 0.42 | 0.21 |
| rest | 2.11 | 1.85 | 2.00 | 1.57 | 1.70 | 1.97 | 1.19 |
| Total | 100.16 | 99.99 | 100.28 | 99.87 | 99.93 | 100.09 | 99.55 |
| | | | | | | | |
| Mg# | 8.6 | 4.6 | 42.5 | 34.7 | 26.4 | 20.1 | 61.0 |

| | **84 103** | **84 104** | **84 127** | **84 132** | **84 133** | **84 134** | **84 153** |
|---|---|---|---|---|---|---|---|
| $\mathrm{Cs_{INAA}}$ | 2.8 | 5.0 | 1.5 | 1.1 | 1.7 | 1.5 | 1.8 |
| Ba | 585 | 635 | 260 | 265 | 325 | 380 | 265 |
| Rb | 101 | 121 | 38 | 39 | 52 | 60 | 34 |
| Sr | 114 | 101 | 189 | 152 | 146 | 134 | 137 |
| Pb | 16 | 17 | 7 | 7 | 9 | 11 | 5 |
| La | 36 | 40 | 14 | 16 | 19 | 24 | 11 |
| $\mathrm{La_{INAA}}$ | 35.0 | 39.0 | 13.2 | 13.8 | 17.6 | 22.0 | 10.4 |
| Ce | 83 | 88 | 34 | 33 | 47 | 54 | 27 |
| $\mathrm{Ce_{INAA}}$ | 82.0 | 87.0 | 29.5 | 32.0 | 40.5 | 49.0 | 23.5 |
| $\mathrm{Nd_{INAA}}$ | 41.5 | 42.5 | 14.6 | 16.2 | 20.0 | 24.0 | 11.8 |
| $\mathrm{Sm_{INAA}}$ | 9.5 | 10.2 | 3.45 | 3.75 | 4.75 | 5.8 | 2.95 |
| $\mathrm{Eu_{INAA}}$ | 1.86 | 1.75 | 1.01 | 1.09 | 1.23 | 1.45 | 0.8 |
| $\mathrm{Gd_{INAA}}$ | 9.5 | 9.7 | 3.6 | 3.8 | 4.8 | 6.2 | 2.3 |
| $\mathrm{Tb_{INAA}}$ | 1.69 | 1.74 | 0.66 | 0.73 | 0.90 | 1.06 | 0.57 |
| $\mathrm{Ho_{INAA}}$ | 2.5 | 2.6 | 0.85 | 1 | 1.3 | 1.5 | 0.75 |
| $\mathrm{Yb_{INAA}}$ | 6.6 | 7 | 2.7 | 2.85 | 3.55 | 4.4 | 2.25 |
| $\mathrm{Lu_{INAA}}$ | 0.99 | 1.03 | 0.41 | 0.44 | 0.54 | 0.67 | 0.36 |
| Y | 59 | 59 | 22 | 23 | 31 | 37 | 19 |
| Th | 13 | 14 | 3 | 6 | 9 | 6 | 5 |
| $\mathrm{Th_{INAA}}$ | 9.7 | 11.2 | 4.3 | 4.4 | 5.5 | 6.1 | 3.4 |
| U | 6 | 2 | 3 | 2 | 2 | 2 | 1 |
| $\mathrm{U_{INAA}}$ | 5.2 | 3.1 | 1 | 0.9 | 1.2 | 1.5 | 0.9 |
| Zr | 273 | 334 | 108 | 115 | 152 | 176 | 92 |
| $\mathrm{Hf_{INAA}}$ | 6.6 | 7.7 | 2.4 | 2.6 | 3.4 | 3.9 | 1.9 |
| Nb | 14.5 | 16 | 4.5 | 6 | 7 | 8 | 4.5 |
| $\mathrm{Sc_{INAA}}$ | 23 | 17.8 | 33 | 35 | 38 | 35 | 41 |
| V | 1 | 1 | 176 | 220 | 336 | 149 | 209 |
| Cr | 1 | 1 | 1 | 1 | 1 | 1 | 111 |
| Mn | 1370 | 1060 | 1050 | 1100 | 1240 | 1180 | 1280 |
| Ni | 3 | 1 | 27 | 16 | 11 | 3 | 77 |
| Cu | 37 | 19 | 109 | 135 | 157 | 103 | 72 |
| Zn | 128 | 111 | 75 | 81 | 97 | 102 | 74 |
| Ga | 19.5 | 18.0 | 19.5 | 21.0 | 21.0 | 21.5 | 16.0 |

| | **84 155** | **84 156** | **84 157** | **84 159** | **84 160** | **84 161** | **84 163** |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 53.70 | 53.75 | 53.52 | 53.34 | 53.32 | 54.93 | 55.97 |
| $TiO_2$ | 0.58 | 0.51 | 0.49 | 0.56 | 0.69 | 0.71 | 0.98 |
| $Al_2O_3$ | 14.56 | 14.78 | 13.78 | 15.12 | 17.56 | 15.03 | 16.02 |
| $Fe_2O_3$ | 1.28 | 0.98 | 0.93 | 1.16 | 1.49 | 1.74 | 2.20 |
| FeO | 7.26 | 7.17 | 7.58 | 7.27 | 7.00 | 8.56 | 7.93 |
| MnO | 0.16 | 0.16 | 0.17 | 0.16 | 0.15 | 0.18 | 0.15 |
| MgO | 7.25 | 8.08 | 9.08 | 6.78 | 4.08 | 4.32 | 2.31 |
| CaO | 11.15 | 11.65 | 11.56 | 11.50 | 11.20 | 9.83 | 8.70 |
| $Na_2O$ | 1.59 | 1.69 | 1.44 | 1.61 | 1.98 | 2.13 | 2.58 |
| $Na_2O_{INAA}$ | 1.45 | 1.45 | 1.27 | 1.48 | 1.81 | 1.88 | 2.28 |
| $K_2O$ | 0.76 | 0.67 | 0.63 | 0.74 | 0.85 | 1.06 | 1.37 |
| $P_2O_5$ | 0.08 | 0.07 | 0.07 | 0.08 | 0.10 | 0.12 | 0.15 |
| S | 0.04 | 0.04 | 0.04 | 0.04 | 0.06 | 0.08 | 0.08 |
| $H_2O+$ | 0.58 | 0.57 | 0.55 | 0.80 | 0.88 | 1.10 | 1.42 |
| $H_2O-$ | 0.25 | 0.33 | 0.30 | 0.33 | 0.29 | 0.42 | 0.41 |
| $CO_2$ | 0.14 | 0.09 | 0.13 | 0.11 | 0.48 | 0.15 | 0.20 |
| rest | 0.14 | 0.14 | 0.15 | 0.13 | 0.12 | 0.15 | 0.15 |
| | 99.52 | 100.68 | 100.42 | 99.73 | 100.25 | 100.51 | 100.62 |
| O=S | 0.02 | 0.02 | 0.02 | 0.02 | 0.03 | 0.04 | 0.04 |
| Total | 99.50 | 100.66 | 100.40 | 99.71 | 100.22 | 100.47 | 100.58 |
| | | | | | | | |
| Q | 7.06 | 4.90 | 4.82 | 6.59 | 7.82 | 9.44 | 11.91 |
| Or | 4.49 | 3.96 | 3.72 | 4.37 | 5.02 | 6.26 | 8.10 |
| Ab | 13.45 | 14.30 | 12.18 | 13.62 | 16.75 | 18.02 | 21.83 |
| An | 30.35 | 30.76 | 29.28 | 31.84 | 36.52 | 28.32 | 28.08 |
| Di | 19.94 | 21.62 | 22.43 | 20.18 | 15.25 | 16.39 | 11.93 |
| Hy | 19.94 | 21.42 | 24.37 | 18.77 | 13.36 | 16.02 | 11.11 |
| Mt | 1.86 | 1.42 | 1.35 | 1.68 | 2.16 | 2.52 | 3.19 |
| Il | 1.10 | 0.97 | 0.93 | 1.06 | 1.31 | 1.35 | 1.86 |
| Ap | 0.19 | 0.16 | 0.16 | 0.19 | 0.23 | 0.28 | 0.35 |
| rest | 0.97 | 0.99 | 0.98 | 1.24 | 1.65 | 1.67 | 2.03 |
| Total | 99.35 | 100.50 | 100.22 | 99.54 | 100.07 | 100.27 | 100.39 |
| | | | | | | | |
| Mg# | 63.9 | 67.3 | 68.9 | 62.6 | 50.1 | 46.7 | 32.3 |

| | 84 155 | 84 156 | 84 157 | 84 159 | 84 160 | 84 161 | 84 163 |
|---|---|---|---|---|---|---|---|
| $Cs_{INAA}$ | 1.2 | 0.9 | 0.9 | 0.5 | 1.4 | 0.7 | 2.3 |
| Ba | 185 | 165 | 150 | 175 | 200 | 250 | 305 |
| Rb | 28 | 24 | 23 | 27 | 31 | 39 | 51 |
| Sr | 116 | 110 | 105 | 118 | 141 | 130 | 147 |
| Pb | 5 | 4 | 3 | 6 | 6 | 6 | 9 |
| La | 11 | 9 | 9 | 11 | 12 | 15 | 18 |
| $La_{INAA}$ | 9.4 | 8.5 | 7.7 | 9.2 | 11.0 | 13.4 | 16.8 |
| Ce | 21 | 22 | 19 | 22 | 29 | 30 | 43 |
| $Ce_{INAA}$ | 20.5 | 19.4 | 18.0 | 20.5 | 25.0 | 31.0 | 39.5 |
| $Nd_{INAA}$ | 10.2 | 9.2 | 8.8 | 10.2 | 12.2 | 15.0 | 19.0 |
| $Sm_{INAA}$ | 2.65 | 2.4 | 2.3 | 2.5 | 3.05 | 3.7 | 4.65 |
| $Eu_{INAA}$ | 0.73 | 0.68 | 0.66 | 0.75 | 0.9 | 0.98 | 1.17 |
| $Gd_{INAA}$ | 2.7 | 2.5 | 2.3 | 2.5 | 3.1 | 3.7 | 4.6 |
| $Tb_{INAA}$ | 0.49 | 0.46 | 0.47 | 0.49 | 0.55 | 0.69 | 0.87 |
| $Ho_{INAA}$ | 0.7 | 0.65 | 0.6 | 0.65 | 0.75 | 0.95 | 1.25 |
| $Yb_{INAA}$ | 2.05 | 1.88 | 1.86 | 2 | 2.3 | 2.85 | 3.35 |
| $Lu_{INAA}$ | 0.33 | 0.3 | 0.3 | 0.32 | 0.35 | 0.44 | 0.52 |
| Y | 18 | 16 | 15 | 17 | 19 | 24 | 29 |
| Th | 5 | 3 | 2 | 5 | 4 | 7 | 7 |
| $Th_{INAA}$ | 3.2 | 2.9 | 2.7 | 3.1 | 3.5 | 4.1 | 5.3 |
| U | 1 | 1 | 3 | 1 | 3 | 1 | 1 |
| $U_{INAA}$ | 0.8 | 0.8 | 1.1 | 1.2 | 0.8 | 1.2 | 1.5 |
| Zr | 82 | 72 | 67 | 82 | 96 | 118 | 149 |
| $Hf_{INAA}$ | 1.6 | 1.5 | 1.4 | 1.7 | 2 | 2.5 | 3.2 |
| Nb | 4 | 3 | 3.5 | 4 | 5 | 5 | 7 |
| $Sc_{INAA}$ | 40 | 40 | 43 | 40 | 35 | 42 | 34 |
| V | 205 | 207 | 222 | 209 | 191 | 215 | 192 |
| Cr | 144 | 195 | 244 | 90 | 6 | 1 | 1 |
| Mn | 1230 | 1250 | 1320 | 1250 | 1140 | 1360 | 1180 |
| Ni | 83 | 95 | 114 | 79 | 41 | 38 | 16 |
| Cu | 67 | 60 | 62 | 69 | 85 | 144 | 120 |
| Zn | 70 | 65 | 70 | 69 | 70 | 91 | 94 |
| Ga | 16 | 15 | 14 | 17 | 18.5 | 18.5 | 20.5 |

| | **84 165** | **84 166** | **84 264** | **84 268** | **84 272** | **84 276** | **84 279** |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 55.79 | 57.67 | 53.82 | 54.14 | 54.22 | 53.76 | 54.20 |
| $TiO_2$ | 1.02 | 0.90 | 0.66 | 0.70 | 0.69 | 0.66 | 0.66 |
| $Al_2O_3$ | 15.81 | 16.48 | 15.99 | 15.45 | 15.55 | 14.69 | 13.88 |
| $Fe_2O_3$ | 1.99 | 1.48 | 1.85 | 2.05 | 1.83 | 1.99 | 1.60 |
| FeO | 8.32 | 7.88 | 7.27 | 7.28 | 7.32 | 7.24 | 7.63 |
| MnO | 0.15 | 0.13 | 0.18 | 0.16 | 0.16 | 0.17 | 0.17 |
| MgO | 2.17 | 1.57 | 5.07 | 5.12 | 5.60 | 6.33 | 6.82 |
| CaO | 8.84 | 7.94 | 10.88 | 10.80 | 10.31 | 10.77 | 10.95 |
| $Na_2O$ | 2.46 | 2.85 | 1.92 | 1.97 | 2.37 | 1.77 | 1.87 |
| $Na_2O_{INAA}$ | 2.43 | 2.66 | 1.79 | 1.81 | 2.21 | 1.66 | 1.65 |
| $K_2O$ | 1.37 | 1.61 | 1.02 | 0.95 | 0.99 | 0.86 | 0.87 |
| $P_2O_5$ | 0.15 | 0.17 | 0.11 | 0.12 | 0.11 | 0.09 | 0.10 |
| S | 0.08 | 0.08 | 0.04 | 0.05 | 0.06 | | |
| $H_2O$ + | 1.44 | 1.65 | 0.69 | 0.49 | 0.82 | 1.37 | 1.18 |
| $H_2O$ - | 0.28 | 0.22 | 0.58 | 0.42 | 0.41 | 0.36 | 0.26 |
| $CO_2$ | 0.16 | 0.22 | 0.07 | 0.11 | 0.12 | 0.11 | 0.10 |
| rest | 0.15 | 0.15 | 0.13 | 0.13 | 0.13 | 0.13 | 0.14 |
| | 100.18 | 101.00 | 100.28 | 99.94 | 100.69 | 100.30 | 100.43 |
| O=S | 0.04 | 0.04 | 0.02 | 0.02 | 0.03 | | |
| Total | 100.14 | 100.96 | 100.26 | 99.92 | 100.66 | 100.30 | 100.43 |
| | | | | | | | |
| Q | 12.12 | 12.93 | 7.74 | 8.50 | 6.12 | 7.98 | 7.00 |
| Or | 8.10 | 9.51 | 6.03 | 5.61 | 5.85 | 5.08 | 5.14 |
| Ab | 20.82 | 24.12 | 16.25 | 16.67 | 20.05 | 14.98 | 15.82 |
| An | 28.05 | 27.42 | 32.00 | 30.51 | 28.87 | 29.60 | 26.91 |
| Di | 12.60 | 9.32 | 17.51 | 18.34 | 17.70 | 19.00 | 21.89 |
| Hy | 11.22 | 11.13 | 15.06 | 14.54 | 16.33 | 17.35 | 18.19 |
| Mt | 2.89 | 2.15 | 2.68 | 2.97 | 2.65 | 2.89 | 2.32 |
| Il | 1.94 | 1.71 | 1.25 | 1.33 | 1.31 | 1.25 | 1.25 |
| Ap | 0.35 | 0.40 | 0.26 | 0.28 | 0.26 | 0.21 | 0.23 |
| rest | 1.88 | 2.09 | 1.34 | 1.02 | 1.35 | 1.84 | 1.54 |
| Total | 99.97 | 100.78 | 100.12 | 99.77 | 100.49 | 100.18 | 100.29 |
| | | | | | | | |
| Mg# | 30.6 | 25.9 | 53.8 | 53.5 | 56.1 | 59.0 | 60.7 |

| | **84 165** | **84 166** | **84 264** | **84 268** | **84 272** | **84 276** | **84 279** |
|---|---|---|---|---|---|---|---|
| $\mathrm{Cs}_{\mathrm{INAA}}$ | 2.6 | 2.7 | 0.9 | 0.8 | 2.2 | 1.2 | 1.0 |
| Ba | 310 | 345 | 230 | 210 | 230 | 210 | 215 |
| Rb | 50 | 60 | 36 | 34 | 36 | 32 | 31 |
| Sr | 141 | 151 | 143 | 126 | 1223 | 107 | 104 |
| Pb | 8 | 9 | 7 | 6 | 6 | 6 | 6 |
| La | 18 | 20 | 13 | 13 | 12 | 11 | 12 |
| $\mathrm{La}_{\mathrm{INAA}}$ | 17.8 | 20.0 | 12.0 | 12.2 | 11.6 | 11.0 | 10.8 |
| Ce | 43 | 47 | 28 | 30 | 28 | 23 | 25 |
| $\mathrm{Ce}_{\mathrm{INAA}}$ | 39.5 | 46 | 27.5 | 27.5 | 26.5 | 24.5 | 24 |
| $\mathrm{Nd}_{\mathrm{INAA}}$ | 20.5 | 23 | 13 | 13 | 13 | 12 | 11.8 |
| $\mathrm{Sm}_{\mathrm{INAA}}$ | 4.65 | 5.3 | 2.65 | 3.45 | 3.25 | 3.1 | 3.1 |
| $\mathrm{Eu}_{\mathrm{INAA}}$ | 1.23 | 1.33 | 0.96 | 0.93 | 0.91 | 0.86 | 0.82 |
| $\mathrm{Gd}_{\mathrm{INAA}}$ | 4.6 | 5.1 | 3.5 | 3.4 | 3.4 | 3.2 | 3.3 |
| $\mathrm{Tb}_{\mathrm{INAA}}$ | 0.82 | 0.92 | 0.62 | 0.62 | 0.61 | 0.58 | 0.57 |
| $\mathrm{Ho}_{\mathrm{INAA}}$ | 1.1 | 1.2 | 0.7 | 0.95 | 0.9 | 0.85 | 0.85 |
| $\mathrm{Yb}_{\mathrm{INAA}}$ | 3.5 | 3.7 | 2.4 | 2.55 | 2.45 | 2.3 | 2.25 |
| $\mathrm{Lu}_{\mathrm{INAA}}$ | 0.53 | 0.56 | 0.4 | 0.41 | 0.39 | 0.39 | 0.39 |
| Y | 29 | 30 | 21 | 21 | 21 | 20 | 20 |
| Th | 5 | 6 | 4 | 8 | 5 | 3 | 4 |
| $\mathrm{Th}_{\mathrm{INAA}}$ | 5.5 | 6 | 4.5 | 4.4 | 4.3 | 3.6 | 4.2 |
| U | 2 | 2 | 1 | 2 | 1 | 1 | 2 |
| $\mathrm{U}_{\mathrm{INAA}}$ | 1 | 1.2 | 1.1 | 0.9 | 1.1 | 1 | 1.3 |
| Zr | 150 | 168 | 104 | 105 | 100 | 97 | 95 |
| $\mathrm{Hf}_{\mathrm{INAA}}$ | 3.2 | 3.8 | 2.2 | 2.2 | 2.1 | 2 | 1.9 |
| Nb | 7 | 7.5 | 4.5 | 5.5 | 4 | 4.5 | 4.5 |
| $\mathrm{Sc}_{\mathrm{INAA}}$ | 36 | 27 | 40 | 40 | 41 | 41 | 43 |
| V | 183 | 132 | 200 | 217 | 211 | 213 | 221 |
| Cr | 1 | 1 | 17 | 12 | 25 | 44 | 64 |
| Mn | 1170 | 1000 | 1380 | 1270 | 1270 | 1310 | 1350 |
| Ni | 14 | 8 | 49 | 50 | 58 | 66 | 74 |
| Cu | 121 | 86 | 86 | 84 | 82 | 77 | 73 |
| Zn | 93 | 81 | 75 | 78 | 73 | 77 | 74 |
| Ga | 19.5 | 20.5 | 18.0 | 17.0 | 17.5 | 17.5 | 16.5 |

| | **84 283** | **84 288** | **84 291** | **84 295** | **84 299** |
|---|---|---|---|---|---|
| $SiO_2$ | 53.57 | 53.47 | 52.86 | 54.00 | 54.01 |
| $TiO_2$ | 0.63 | 0.42 | 0.45 | 0.56 | 0.63 |
| $Al_2O_3$ | 14.88 | 12.46 | 14.24 | 14.52 | 14.49 |
| $Fe_2O_3$ | 2.22 | 1.64 | 1.57 | 1.04 | 2.04 |
| FeO | 6.79 | 6.49 | 6.36 | 7.37 | 6.99 |
| MnO | 0.17 | 0.17 | 0.16 | 0.16 | 0.17 |
| MgO | 6.17 | 11.04 | 9.58 | 7.76 | 6.78 |
| CaO | 11.03 | 11.54 | 11.34 | 11.03 | 10.41 |
| $Na_2O$ | 2.09 | 1.38 | 1.41 | 1.74 | 2.07 |
| $Na_2O_{INAA}$ | 1.73 | 1.13 | 1.32 | 1.63 | 1.83 |
| $K_2O$ | 0.87 | 0.51 | 0.60 | 0.75 | 0.94 |
| $P_2O_5$ | 0.12 | 0.06 | 0.08 | 0.10 | 0.14 |
| S | 0.05 | 0.03 | 0.03 | 0.04 | |
| $H_2O$ + | 0.70 | 0.56 | 0.66 | 0.84 | 0.92 |
| $H_2O$ - | 0.33 | 0.57 | 0.53 | 0.29 | 0.64 |
| $CO_2$ | 0.12 | 0.14 | 0.18 | 0.15 | 0.15 |
| rest | 0.14 | 0.17 | 0.15 | 0.15 | 0.17 |
| | 99.88 | 100.65 | 100.20 | 100.50 | 100.55 |
| O=S | 0.02 | 0.01 | 0.01 | 0.02 | |
| Total | 99.86 | 100.64 | 100.19 | 100.48 | 100.55 |
| | | | | | |
| Q | 6.54 | 4.44 | 4.88 | 5.89 | 6.63 |
| Or | 5.14 | 3.01 | 3.55 | 4.43 | 5.56 |
| Ab | 17.69 | 11.68 | 11.93 | 14.72 | 17.52 |
| An | 28.65 | 26.30 | 30.75 | 29.59 | 27.47 |
| Di | 20.63 | 24.55 | 20.13 | 19.94 | 18.95 |
| Hy | 15.21 | 25.89 | 24.10 | 21.65 | 18.08 |
| Mt | 3.22 | 2.38 | 2.28 | 1.51 | 2.96 |
| Il | 1.20 | 0.80 | 0.85 | 1.06 | 1.20 |
| Ap | 0.28 | 0.14 | 0.19 | 0.23 | 0.33 |
| rest | 1.15 | 1.27 | 1.37 | 1.28 | 1.71 |
| Total | 99.71 | 100.46 | 100.03 | 100.30 | 100.41 |
| | | | | | |
| Mg# | 59.0 | 74.0 | 71.6 | 65.7 | 61.2 |

| | **84 283** | **84 288** | **84 291** | **84 295** | **84 299** |
|---|---|---|---|---|---|
| $Cs_{INAA}$ | 0.7 | 1.1 | 0.5 | 1.2 | 1.4 |
| Ba | 205 | 120 | 140 | 180 | 400 |
| Rb | 31 | 18 | 22 | 28 | 33 |
| Sr | 119 | 87 | 101 | 107 | 147 |
| Pb | 6 | 3 | 3 | 4 | 6 |
| La | 11 | 8 | 8 | 12 | 12 |
| $La_{INAA}$ | 11.0 | 6.6 | 7.4 | 9.5 | 11.0 |
| Ce | 22 | 16 | 15 | 20 | 23 |
| $Ce_{INAA}$ | 24.5 | 15.8 | 16.8 | 22.5 | 25.5 |
| $Nd_{INAA}$ | 12.4 | 8.1 | 8.4 | 11 | 12.4 |
| $Sm_{INAA}$ | 3.15 | 1.95 | 2.15 | 2.75 | 3.1 |
| $Eu_{INAA}$ | 0.83 | 0.57 | 0.63 | 0.75 | 0.85 |
| $Gd_{INAA}$ | 3.1 | 2.1 | 2.3 | 2.8 | 3.1 |
| $Tb_{INAA}$ | 0.57 | 0.39 | 0.39 | 0.52 | 0.57 |
| $Ho_{INAA}$ | 0.85 | 0.55 | 0.6 | 0.8 | 0.9 |
| $Yb_{INAA}$ | 2.35 | 1.5 | 1.65 | 2.05 | 2.3 |
| $Lu_{INAA}$ | 0.38 | 0.27 | 0.28 | 0.35 | 0.38 |
| Y | 20 | 13 | 14 | 17 | 20 |
| Th | 2 | 4 | 3 | 5 | 3 |
| $Th_{INAA}$ | 3.9 | 2.3 | 2.6 | 3.6 | 4 |
| U | 1 | 1 | 2 | 1 | 1 |
| $U_{INAA}$ | 1 | 0.7 | 0.6 | 1 | 1.2 |
| Zr | 95 | 59 | 65 | 80 | 94 |
| $Hf_{INAA}$ | 2 | 1.2 | 1.3 | 1.8 | 2.1 |
| Nb | 4.5 | 2 | 3 | 4 | 4 |
| $Sc_{INAA}$ | 41 | 44 | 39 | 41 | 42 |
| V | 210 | 224 | 203 | 208 | 222 |
| Cr | 60 | 372 | 302 | 180 | 110 |
| Mn | 1290 | 1340 | 1250 | 1270 | 1340 |
| Ni | 70 | 143 | 122 | 93 | 77 |
| Cu | 77 | 49 | 50 | 65 | 75 |
| Zn | 74 | 61 | 62 | 68 | 76 |
| Ga | 16.5 | 13.5 | 14.5 | 15.5 | 16.5 |

## 4.2 DATABASE OF FERRAR SAMPLES

| | **P-1-2** | **P-1-3** | **P-1-4** | **P-1-5** | **P-1-6** | **P-1-7** | **P-1-8** |
|---|---|---|---|---|---|---|---|
| | **87 85** | **87 86** | **87 87** | **87 88** | **87 89** | **87 90** | **87 91** |
| $SiO_2$ | 82.48 | 50.80 | 53.49 | 53.21 | 53.66 | 53.43 | 53.78 |
| $TiO_2$ | 0.46 | 1.12 | 0.77 | 0.74 | 0.74 | 0.73 | 0.73 |
| $Al_2O_3$ | 7.99 | 21.45 | 14.41 | 14.23 | 14.35 | 14.30 | 14.38 |
| $Fe_2O_3$ | 0.50 | 1.13 | 2.12 | 2.04 | 2.06 | 2.18 | 2.32 |
| FeO | 2.11 | 8.37 | 7.28 | 7.45 | 7.56 | 7.36 | 7.20 |
| MnO | 0.05 | 0.07 | 0.13 | 0.15 | 0.16 | 0.15 | 0.16 |
| MgO | 1.20 | 4.09 | 6.02 | 6.04 | 6.19 | 6.29 | 6.35 |
| CaO | 0.82 | 0.70 | 10.52 | 10.57 | 10.63 | 10.51 | 10.56 |
| $Na_2O$ | 2.98 | 0.82 | 2.10 | 2.07 | 2.12 | 2.01 | 2.06 |
| $K_2O$ | 0.27 | 5.44 | 0.74 | 0.78 | 0.83 | 0.82 | 0.86 |
| $P_2O_5$ | 0.18 | 0.23 | 0.13 | 0.12 | 0.12 | 0.12 | 0.12 |
| S | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 |
| $H_2O+$ | 1.30 | 4.93 | 1.51 | 1.35 | 1.17 | 1.10 | 1.07 |
| $H_2O-$ | 0.11 | 0.51 | 0.56 | 0.50 | 0.39 | 0.29 | 0.35 |
| $CO_2$ | 0.09 | 0.11 | 0.09 | 0.08 | 0.11 | 0.10 | 0.10 |
| Total | 100.55 | 99.78 | 99.89 | 99.34 | 100.10 | 99.40 | 100.05 |
| | | | | | | | |
| Ba | 66 | 1150 | 205 | 210 | 215 | 215 | 220 |
| Rb | 15.0 | 307.0 | 20.0 | 23.5 | 25.5 | 27.0 | 28.5 |
| Sr | 232 | 355 | 142 | 145 | 142 | 145 | 153 |
| Pb | 20 | 38 | 5 | 5 | 6 | 4 | 5 |
| Y | 28 | 37 | 22 | 22 | 21 | 19 | 20 |
| Zr | 214 | 112 | 105 | 101 | 99 | 98 | 98 |
| Nb | 8.0 | 20.0 | 5.0 | 5.0 | 5.0 | 4.5 | 5.0 |
| La | 23 | 84 | 12 | 11 | 12 | 11 | 11 |
| Ce | 50 | 186 | 26 | 25 | 27 | 26 | 26 |
| V | 33 | 171 | 233 | 224 | 226 | 215 | 218 |
| Cr | 32 | 150 | 106 | 112 | 120 | 120 | 132 |
| Mn | 455 | 560 | 1100 | 1200 | 1250 | 1190 | 1210 |
| Ni | 20 | 68 | 86 | 92 | 88 | 91 | 93 |
| Cu | 30 | 55 | 88 | 91 | 87 | 94 | 90 |
| Zn | 40 | 109 | 72 | 71 | 72 | 69 | 65 |
| Ga | 7.0 | 32.0 | 16.5 | 17.0 | 16.0 | 16.5 | 16.5 |

| | **P-1-10** | **P-1-11** | **P-1-12** | **P-1-13** | **P-1-14** | **P-1-15** | **P-1-16** |
|---|---|---|---|---|---|---|---|
| | **87 92** | **87 93** | **87 94** | **87 95** | **87 96** | **87 97** | **87 98** |
| $SiO_2$ | 54.40 | 54.41 | 53.57 | 54.13 | 53.49 | 54.13 | 53.95 |
| $TiO_2$ | 0.71 | 0.71 | 0.70 | 0.69 | 0.69 | 0.68 | 0.68 |
| $Al_2O_3$ | 14.58 | 14.75 | 14.69 | 14.79 | 14.54 | 14.82 | 15.01 |
| $Fe_2O_3$ | 2.30 | 2.49 | 2.08 | 1.80 | 2.11 | 2.00 | 1.91 |
| FeO | 7.13 | 6.89 | 7.31 | 7.39 | 7.16 | 7.12 | 7.13 |
| MnO | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.15 | 0.16 |
| MgO | 6.32 | 6.47 | 6.50 | 6.59 | 6.62 | 6.60 | 6.66 |
| CaO | 10.49 | 10.63 | 10.77 | 10.95 | 10.81 | 10.88 | 11.10 |
| $Na_2O$ | 2.10 | 2.15 | 2.05 | 2.03 | 2.09 | 2.12 | 2.01 |
| $K_2O$ | 0.91 | 0.85 | 0.83 | 0.82 | 0.76 | 0.78 | 0.75 |
| $P_2O_5$ | 0.12 | 0.11 | 0.12 | 0.11 | 0.12 | 0.11 | 0.12 |
| S | 0.00 | 0.03 | 0.02 | 0.02 | 0.04 | 0.01 | 0.01 |
| $H_2O+$ | 1.06 | 0.92 | 1.13 | 0.96 | 1.05 | 1.03 | 0.96 |
| $H_2O-$ | 0.35 | 0.27 | 0.36 | 0.34 | 0.35 | 0.31 | 0.34 |
| $CO_2$ | 0.12 | 0.10 | 0.14 | 0.19 | 0.18 | 0.08 | 0.13 |
| Total | 100.75 | 100.94 | 100.43 | 100.97 | 100.17 | 100.82 | 100.92 |
| | | | | | | | |
| Ba | 225 | 230 | 205 | 210 | 200 | 205 | 195 |
| Rb | 30.0 | 27.5 | 29.0 | 26.5 | 24.0 | 24.0 | 24.0 |
| Sr | 144 | 152 | 146 | 148 | 149 | 144 | 143 |
| Pb | 4 | 4 | 5 | 5 | 5 | 4 | 5 |
| Y | 20 | 19 | 20 | 19 | 19 | 19 | 19 |
| Zr | 97 | 92 | 86 | 92 | 87 | 88 | 86 |
| Nb | 5.0 | 5.0 | 5.0 | 4.0 | 5.0 | 4.0 | 4.5 |
| La | 11 | 12 | 10 | 12 | 10 | 11 | 11 |
| Ce | 23 | 28 | 23 | 25 | 23 | 24 | 25 |
| V | 216 | 205 | 212 | 208 | 214 | 210 | 216 |
| Cr | 140 | 129 | 143 | 147 | 151 | 146 | 153 |
| Mn | 1250 | 1130 | 1200 | 1200 | 1210 | 1190 | 1200 |
| Ni | 92 | 86 | 98 | 92 | 101 | 102 | 97 |
| Cu | 85 | 84 | 86 | 88 | 84 | 80 | 84 |
| Zn | 64 | 63 | 64 | 63 | 62 | 66 | 64 |
| Ga | 16.0 | 16.5 | 16.0 | 16.0 | 16.0 | 16.0 | 16.5 |

| | **P-1-17** | **P-1-18** | **P-1-19** | **P-1-20** | **P-1-21** | **P-1-22** | **P-1-23** |
|---|---|---|---|---|---|---|---|
| | **87 99** | **87 100** | **87 101** | **87 102** | **87 103** | **87 104** | **87 105** |
| $SiO_2$ | 53.38 | 54.00 | 53.41 | 53.35 | 53.81 | 53.18 | 52.97 |
| $TiO_2$ | 0.69 | 0.70 | 0.66 | 0.69 | 0.75 | 0.74 | 0.72 |
| $Al_2O_3$ | 14.93 | 14.67 | 14.83 | 14.89 | 14.21 | 14.79 | 14.88 |
| $Fe_2O_3$ | 1.96 | 2.07 | 1.72 | 1.77 | 1.88 | 2.01 | 1.99 |
| FeO | 7.24 | 7.34 | 7.49 | 7.47 | 7.84 | 7.48 | 7.50 |
| MnO | 0.16 | 0.16 | 0.15 | 0.15 | 0.16 | 0.16 | 0.16 |
| MgO | 6.53 | 6.45 | 6.56 | 6.28 | 6.65 | 6.23 | 6.26 |
| CaO | 11.05 | 10.77 | 10.95 | 10.90 | 10.66 | 10.65 | 10.80 |
| $Na_2O$ | 2.03 | 2.03 | 2.10 | 2.12 | 2.00 | 2.17 | 2.14 |
| $K_2O$ | 0.76 | 0.86 | 0.72 | 0.75 | 0.81 | 0.78 | 0.75 |
| $P_2O_5$ | 0.11 | 0.11 | 0.11 | 0.13 | 0.15 | 0.14 | 0.12 |
| S | 0.03 | 0.02 | 0.01 | 0.02 | 0.01 | | |
| $H_2O+$ | 0.96 | 1.11 | 0.85 | 0.85 | 0.97 | 0.95 | 1.02 |
| $H_2O-$ | 0.40 | 0.39 | 0.33 | 0.31 | 0.35 | 0.31 | 0.39 |
| $CO_2$ | 0.11 | 0.16 | 0.09 | 0.13 | 0.10 | 0.07 | 0.10 |
| Total | 100.34 | 100.84 | 99.98 | 99.81 | 100.35 | 99.66 | 99.80 |
| | | | | | | | |
| Ba | 190 | 230 | 195 | 195 | 215 | 205 | 195 |
| Rb | 25.0 | 29.5 | 21.5 | 21.5 | 26.0 | 24.0 | 22.5 |
| Sr | 145 | 148 | 145 | 145 | 144 | 150 | 150 |
| Pb | 4 | 4 | 4 | 4 | 5 | 4 | 5 |
| Y | 19 | 19 | 18 | 19 | 22 | 20 | 19 |
| Zr | 86 | 92 | 82 | 89 | 96 | 94 | 89 |
| Nb | 4.0 | 4.0 | 3.5 | 5.0 | 4.5 | 4.0 | 4.5 |
| La | 10 | 12 | 10 | 10 | 11 | 10 | 10 |
| Ce | 24 | 25 | 22 | 24 | 28 | 24 | 22 |
| V | 217 | 194 | 201 | 208 | 215 | 218 | 221 |
| Cr | 139 | 100 | 127 | 118 | 108 | 96 | 101 |
| Mn | 1210 | 1070 | 1170 | 1200 | 1220 | 1210 | 1240 |
| Ni | 95 | 80 | 94 | 90 | 94 | 87 | 90 |
| Cu | 83 | 84 | 74 | 84 | 80 | 84 | 83 |
| Zn | 63 | 61 | 62 | 66 | 65 | 68 | 69 |
| Ga | 16.0 | 16.5 | 17.0 | 17.0 | 16.5 | 16.5 | 17.0 |

| | **P-1-24** | **P-1-25** | **P-1-26** | **P-1-27** | **P-1-28** | **P-1-29** | **P-1-30** |
|---|---|---|---|---|---|---|---|
| | **87 106** | **87 107** | **87 108** | **87 109** | **87 110** | **87 111** | **87 112** |
| $SiO_2$ | 53.28 | 52.83 | 53.29 | 53.80 | 53.33 | 52.88 | 52.34 |
| $TiO_2$ | 0.69 | 0.71 | 0.68 | 0.65 | 0.66 | 0.64 | 0.58 |
| $Al_2O_3$ | 14.69 | 14.59 | 14.41 | 15.12 | 14.76 | 14.78 | 15.47 |
| $Fe_2O_3$ | 2.13 | 1.96 | 2.03 | 1.82 | 1.75 | 1.61 | 1.52 |
| FeO | 7.37 | 7.43 | 7.45 | 7.30 | 7.43 | 7.22 | 6.91 |
| MnO | 0.16 | 0.15 | 0.16 | 0.15 | 0.16 | 0.15 | 0.14 |
| MgO | 6.39 | 6.37 | 6.62 | 6.64 | 6.72 | 6.96 | 7.05 |
| CaO | 10.70 | 10.77 | 10.86 | 11.12 | 11.11 | 11.18 | 11.74 |
| $Na_2O$ | 2.13 | 2.06 | 2.02 | 2.05 | 2.02 | 1.97 | 1.88 |
| $K_2O$ | 0.78 | 0.79 | 0.74 | 0.71 | 0.68 | 0.72 | 0.54 |
| $P_2O_5$ | 0.11 | 0.11 | 0.12 | 0.10 | 0.10 | 0.10 | 0.09 |
| S | 0.04 | 0.06 | 0.03 | | | | 0.01 |
| $H_2O+$ | 0.98 | 0.91 | 0.87 | 0.99 | 1.06 | 1.02 | 1.49 |
| $H_2O-$ | 0.44 | 0.39 | 0.40 | 0.40 | 0.32 | 0.48 | 0.59 |
| $CO_2$ | 0.15 | 0.19 | 0.13 | 0.11 | 0.07 | 0.09 | 0.32 |
| Total | 100.04 | 99.32 | 99.81 | 100.96 | 100.17 | 99.80 | 100.67 |
| | | | | | | | |
| Ba | 210 | 205 | 195 | 185 | 190 | 180 | 155 |
| Rb | 25.0 | 24.5 | 22.0 | 21.0 | 19.5 | 21.5 | 15.5 |
| Sr | 149 | 148 | 146 | 145 | 144 | 145 | 146 |
| Pb | 4 | 5 | 4 | 4 | 4 | 4 | 3 |
| Y | 19 | 18 | 19 | 17 | 17 | 18 | 16 |
| Zr | 87 | 88 | 88 | 82 | 80 | 83 | 65 |
| Nb | 4.0 | 4.5 | 5.0 | 4.0 | 4.0 | 3.5 | 3.0 |
| La | 10 | 10 | 11 | 10 | 10 | 8 | 8 |
| Ce | 22 | 21 | 23 | 22 | 23 | 21 | 18 |
| V | 204 | 215 | 206 | 211 | 207 | 214 | 192 |
| Cr | 105 | 114 | 112 | 129 | 120 | 126 | 183 |
| Mn | 1170 | 1210 | 1200 | 1210 | 1200 | 1200 | 1070 |
| Ni | 83 | 84 | 81 | 74 | 73 | 63 | 59 |
| Cu | 83 | 84 | 81 | 74 | 73 | 63 | 59 |
| Zn | 64 | 63 | 64 | 67 | 61 | 62 | 64 |
| Ga | 17.0 | 16.0 | 17.0 | 16.5 | 16.5 | 16.0 | 16.0 |

| | **P-1-31** | **P-1-32** | **P-1-33** | **P-1-34** | **P-1-35** | **P-1-36** | **P-1-37** |
|---|---|---|---|---|---|---|---|
| | **87 113** | **87 114** | **87 115** | **87 116** | **87 117** | **87 118** | **87 119** |
| $SiO_2$ | 52.69 | 53.65 | 53.29 | 53.60 | 51.94 | 51.89 | 53.53 |
| $TiO_2$ | 0.55 | 0.61 | 0.62 | 0.68 | 0.55 | 0.71 | 0.62 |
| $Al_2O_3$ | 15.59 | 15.44 | 15.13 | 14.55 | 21.64 | 14.39 | 14.58 |
| $Fe_2O_3$ | 1.40 | 1.56 | 1.49 | 1.90 | 1.71 | 2.47 | 1.82 |
| FeO | 7.08 | 7.05 | 6.98 | 6.97 | 4.53 | 6.67 | 7.40 |
| MnO | 0.15 | 0.15 | 0.15 | 0.15 | 0.10 | 0.16 | 0.16 |
| MgO | 7.37 | 7.28 | 7.20 | 7.14 | 3.12 | 6.58 | 6.98 |
| CaO | 11.37 | 11.47 | 11.66 | 11.22 | 12.16 | 12.27 | 11.17 |
| $Na_2O$ | 1.89 | 1.93 | 1.87 | 1.86 | 2.42 | 1.94 | 1.95 |
| $K_2O$ | 0.60 | 0.65 | 0.68 | 0.69 | 0.83 | 0.60 | 0.67 |
| $P_2O_5$ | 0.09 | 0.09 | 0.10 | 0.11 | 0.09 | 0.12 | 0.10 |
| S | 0.05 | | 0.01 | | 0.01 | | 0.02 |
| $H_2O+$ | 0.88 | 0.82 | 0.98 | 0.91 | 0.93 | 2.03 | 1.01 |
| $H_2O-$ | 0.35 | 0.34 | 0.31 | 0.32 | 0.20 | 0.57 | 0.30 |
| $CO_2$ | 0.22 | 0.05 | 0.13 | 0.08 | 0.15 | 0.11 | 0.13 |
| Total | 100.28 | 101.09 | 100.60 | 100.18 | 100.38 | 100.51 | 100.44 |
| | | | | | | | |
| Ba | 165 | 175 | 175 | 190 | 185 | 170 | 180 |
| Rb | 17.5 | 19.0 | 21.5 | 21.5 | 31.5 | 17.0 | 21.0 |
| Sr | 144 | 139 | 141 | 136 | 206 | 135 | 144 |
| Pb | 3 | 4 | 4 | 4 | 4 | 3 | 4 |
| Y | 14 | 16 | 17 | 19 | 14 | 19 | 18 |
| Zr | 69 | 72 | 77 | 85 | 71 | 78 | 79 |
| Nb | 2.5 | 4.0 | 4.5 | 4.5 | 4.0 | 5.5 | 3.5 |
| La | 8 | 9 | 9 | 10 | 8 | 9 | 9 |
| Ce | 18 | 22 | 20 | 23 | 19 | 23 | 22 |
| V | 180 | 187 | 198 | 200 | 129 | 224 | 205 |
| Cr | 235 | 217 | 214 | 211 | 27 | 172 | 120 |
| Mn | 1180 | 1120 | 1140 | 1150 | 780 | 1320 | 1230 |
| Ni | 111 | 107 | 112 | 106 | 39 | 108 | 104 |
| Cu | 64 | 67 | 70 | 73 | 49 | 78 | 82 |
| Zn | 59 | 58 | 58 | 60 | 43 | 63 | 64 |
| Ga | 15.0 | 16.0 | 16.0 | 15.0 | 19.0 | 16.0 | 15.5 |

| | **P-1-38** | **P-1-39** | **P-1-40** | **P-1-41** | **P-1-42** | **P-1-43** | **P-1-44** |
|---|---|---|---|---|---|---|---|
| | **87 120** | **87 121** | **87 122** | **87 123** | **87 124** | **87 125** | **87 126** |
| $SiO_2$ | 51.96 | 54.20 | 53.59 | 54.61 | 54.27 | 54.41 | 54.21 |
| $TiO_2$ | 0.36 | 0.79 | 0.62 | 0.94 | 0.78 | 0.82 | 0.78 |
| $Al_2O_3$ | 15.35 | 14.12 | 15.09 | 13.65 | 14.33 | 14.22 | 14.31 |
| $Fe_2O_3$ | 1.23 | 2.55 | 2.19 | 2.91 | 2.13 | 2.11 | 1.74 |
| FeO | 6.86 | 7.74 | 6.91 | 8.25 | 7.66 | 8.02 | 8.11 |
| MnO | 0.15 | 0.17 | 0.15 | 0.17 | 0.16 | 0.16 | 0.16 |
| MgO | 8.56 | 5.77 | 6.50 | 5.18 | 5.86 | 5.80 | 6.05 |
| CaO | 12.83 | 10.20 | 10.99 | 9.76 | 10.43 | 10.31 | 10.46 |
| $Na_2O$ | 1.75 | 2.23 | 2.00 | 2.19 | 2.04 | 2.13 | 2.11 |
| $K_2O$ | 0.43 | 0.89 | 0.84 | 1.05 | 0.80 | 0.78 | 0.81 |
| $P_2O_5$ | 0.05 | 0.12 | 0.11 | 0.15 | 0.13 | 0.14 | 0.13 |
| S | | | | | 0.01 | 0.03 | 0.02 |
| $H_2O+$ | 0.81 | 1.07 | 0.99 | 1.17 | 1.09 | 1.21 | 1.31 |
| $H_2O-$ | 0.19 | 0.35 | 0.40 | 0.36 | 0.32 | 0.41 | 0.39 |
| $CO_2$ | 0.12 | 0.10 | 0.11 | 0.13 | 0.14 | 0.14 | 0.16 |
| Total | 100.65 | 100.30 | 100.49 | 100.52 | 100.15 | 100.69 | 100.75 |
| | | | | | | | |
| Ba | 110 | 230 | 220 | 290 | 225 | 225 | 215 |
| Rb | 15.0 | 28.5 | 29.5 | 31.0 | 22.5 | 20.5 | 19.0 |
| Sr | 143 | 160 | 153 | 160 | 152 | 153 | 159 |
| Pb | 2 | 5 | 3 | 6 | 4 | 5 | 5 |
| Y | 10 | 21 | 18 | 25 | 22 | 23 | 22 |
| Zr | 35 | 96 | 81 | 119 | 106 | 106 | 101 |
| Nb | 2.0 | 5.5 | 3.5 | 6.5 | 5.5 | 6.5 | 5.0 |
| La | 4 | 12 | 10 | 14 | 11 | 12 | 11 |
| Ce | 9 | 28 | 24 | 32 | 27 | 27 | 27 |
| V | 190 | 234 | 191 | 237 | 228 | 237 | 234 |
| Cr | 125 | 19 | 112 | 36 | 97 | 89 | 104 |
| Mn | 1230 | 1270 | 1170 | 1230 | 1260 | 1250 | 1260 |
| Ni | 130 | 78 | 93 | 60 | 85 | 81 | 90 |
| Cu | 53 | 111 | 87 | 115 | 95 | 98 | 97 |
| Zn | 53 | 72 | 60 | 73 | 73 | 75 | 72 |
| Ga | 14.5 | 17.5 | 16.0 | 17.0 | 17.0 | 17.0 | 17.0 |

| | **P-1-45** | **P-1-46** |
|---|---|---|
| | **87 127** | **87 128** |
| $SiO_2$ | 63.17 | 62.77 |
| $TiO_2$ | 0.73 | 0.58 |
| $Al_2O_3$ | 16.15 | 12.07 |
| $Fe_2O_3$ | 0.68 | 0.52 |
| FeO | 5.11 | 2.95 |
| MnO | 0.06 | 0.54 |
| MgO | 2.79 | 2.19 |
| CaO | 0.67 | 11.06 |
| $Na_2O$ | 1.36 | 2.50 |
| $K_2O$ | 4.48 | 3.42 |
| $P_2O_5$ | 0.18 | 0.17 |
| S | | 0.01 |
| $H_2O+$ | 3.37 | 1.12 |
| $H_2O-$ | 0.49 | 0.22 |
| $CO_2$ | 0.15 | 0.39 |
| Total | 99.39 | 100.51 |
| | | |
| Ba | 1010 | 930 |
| Rb | 209.0 | 116.0 |
| Sr | 239 | 182 |
| Pb | 26 | 21 |
| Y | 34 | 30 |
| Zr | 238 | 253 |
| Nb | 14.0 | 10.0 |
| La | 43 | 39 |
| Ce | 95 | 83 |
| V | 97 | 57 |
| Cr | 97 | 58 |
| Mn | 460 | 4750 |
| Ni | 43 | 26 |
| Cu | 27 | 11 |
| Zn | 90 | 54 |
| Ga | 22.0 | 14.5 |

| | **87 87** | **87 93** | **87 104** | **87 117** | **87 122** | **87 126** |
|---|---|---|---|---|---|---|
| $SiO_2$ | 53.49 | 54.41 | 53.18 | 51.94 | 53.59 | 54.21 |
| $TiO_2$ | 0.77 | 0.71 | 0.74 | 0.55 | 0.62 | 0.78 |
| $Al_2O_3$ | 14.41 | 14.75 | 14.79 | 21.64 | 15.09 | 14.31 |
| $Fe_2O_3$ | 2.12 | 2.49 | 2.01 | 1.71 | 2.19 | 1.74 |
| FeO | 7.28 | 6.89 | 7.48 | 4.53 | 6.91 | 8.11 |
| MnO | 0.13 | 0.16 | 0.16 | 0.10 | 0.15 | 0.16 |
| MgO | 6.02 | 6.47 | 6.23 | 3.12 | 6.50 | 6.05 |
| CaO | 10.52 | 10.63 | 10.65 | 12.16 | 10.99 | 10.46 |
| $Na_2O$ | 2.10 | 2.15 | 2.17 | 2.42 | 2.00 | 2.11 |
| $Na_2O_{INAA}$ | 1.80 | 1.75 | 1.87 | 2.29 | 1.74 | 1.82 |
| $K_2O$ | 0.74 | 0.85 | 0.78 | 0.83 | 0.84 | 0.81 |
| $P_2O_5$ | 0.13 | 0.11 | 0.14 | 0.09 | 0.11 | 0.13 |
| S | 0.02 | 0.03 | 0.00 | 0.01 | 0.00 | 0.02 |
| $H_2O+$ | 1.51 | 0.92 | 0.95 | 0.93 | 0.99 | 1.31 |
| $H_2O-$ | 0.56 | 0.27 | 0.31 | 0.20 | 0.40 | 0.39 |
| $CO_2$ | 0.09 | 0.10 | 0.07 | 0.15 | 0.11 | 0.16 |
| | | | | | | |
| $Cs_{INAA}$ | 0.5 | 0.5 | 0.5 | 0.7 | 0.7 | 0.6 |
| Ba | 205 | 230 | 205 | 185 | 220 | 215 |
| Rb | 20 | 28 | 24 | 32 | 30 | 19 |
| Sr | 142 | 152 | 150 | 206 | 153 | 159 |
| Pb | 5 | 4 | 4 | 4 | 3 | 5 |
| La | 12 | 12 | 10 | 8 | 10 | 11 |
| $La_{INAA}$ | 11.2 | 10.6 | 10.6 | 8.2 | 9.1 | 11.5 |
| Ce | 26 | 28 | 24 | 19 | 24 | 27 |
| $Ce_{INAA}$ | 25.0 | 24.0 | 24.0 | 18.6 | 20.5 | 11.5 |
| $Nd_{INAA}$ | 13.0 | 12.4 | 12.4 | 9.5 | 10.8 | 13.2 |
| $Sm_{INAA}$ | 3.30 | 3.05 | 3.15 | 2.35 | 2.80 | 3.40 |
| $Eu_{INAA}$ | 0.96 | 0.92 | 0.94 | 0.86 | 0.87 | 0.96 |
| $Gd_{INAA}$ | 3.6 | 3.1 | 3.4 | 2.5 | 3.0 | 3.7 |
| $Tb_{INAA}$ | 0.61 | 0.61 | 0.61 | 0.44 | 0.53 | 0.62 |
| $Ho_{INAA}$ | 0.85 | 0.85 | 0.85 | 0.60 | 0.75 | 0.85 |
| $Yb_{INAA}$ | 2.60 | 2.45 | 2.45 | 1.84 | 2.15 | 2.60 |
| $Lu_{INAA}$ | 0.41 | 0.38 | 0.38 | 0.27 | 0.36 | 0.42 |
| Y | 22 | 19 | 20 | 14 | 18 | 22 |
| $Th_{INAA}$ | 3.4 | 3.1 | 3.0 | 2.6 | 2.8 | 3.4 |
| $U_{INAA}$ | 1.3 | 0.9 | 0.9 | 0.6 | 0.7 | 1.1 |

| | **87 87** | **87 93** | **87 104** | **87 117** | **87 122** | **87 126** |
|---|---|---|---|---|---|---|
| Zr | 105 | 92 | 94 | 71 | 81 | 101 |
| Hf $_{INAA}$ | 2.1 | 2.1 | 2.0 | 1.5 | 1.7 | 2.0 |
| Nb | 5 | 5 | 4 | 4 | 3.5 | 5 |
| Sc $_{INAA}$ | 39.6 | 38.7 | 39.3 | 21.8 | 38.8 | 39.6 |
| V | 233 | 205 | 218 | 129 | 191 | 234 |
| Cr | 106 | 129 | 96 | 27 | 112 | 104 |
| Mn | 1100 | 1130 | 1210 | 780 | 1170 | 1260 |
| Ni | 86 | 86 | 87 | 39 | 93 | 90 |
| Cu | 88 | 84 | 84 | 49 | 87 | 97 |
| Zn | 72 | 63 | 68 | 43 | 60 | 72 |
| Ga | 16.5 | 16.5 | 16.5 | 19.0 | 16.0 | 17.0 |

# 4.3 DATABASE OF VICTORIAN AND SOUTH AUSTRALIAN SAMPLES

| | **87 129** | **87 130** | **87 131** | **87 132** | **87 133** | **87 134** | **87 135** |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 46.05 | 52.04 | 54.37 | 47.08 | 55.46 | 54.89 | 55.55 |
| $TiO_2$ | 2.65 | 0.59 | 0.64 | 2.86 | 0.63 | 0.75 | 0.65 |
| $Al_2O_3$ | 15.91 | 14.49 | 14.91 | 15.14 | 15.13 | 15.06 | 14.84 |
| $Fe_2O_3$ | 4.84 | 1.48 | 1.48 | 3.45 | 1.29 | 1.14 | 1.19 |
| FeO | 6.77 | 8.80 | 6.64 | 7.48 | 6.27 | 7.90 | 7.36 |
| MnO | 0.15 | 0.32 | 0.16 | 0.15 | 0.15 | 0.23 | 0.17 |
| MgO | 6.89 | 6.03 | 6.58 | 7.19 | 7.21 | 4.97 | 7.36 |
| CaO | 8.72 | 10.01 | 10.59 | 8.03 | 11.01 | 9.84 | 10.98 |
| $Na_2O$ | 2.46 | 1.94 | 2.00 | 3.47 | 1.96 | 2.13 | 1.87 |
| $K_2O$ | 1.74 | 0.75 | 0.46 | 2.51 | 0.76 | 0.79 | 0.71 |
| $P_2O_5$ | 0.62 | 0.08 | 0.09 | 0.94 | 0.09 | 0.11 | 0.09 |
| S | 0.01 | 0.02 | 0.04 | 0.01 | 0.02 | 0.05 | 0.04 |
| $H_2O+$ | 2.49 | 0.73 | 1.36 | 1.00 | 0.55 | 0.71 | 0.50 |
| $H_2O-$ | 1.08 | 0.67 | 1.24 | 0.32 | 0.54 | 0.77 | 0.22 |
| $CO_2$ | 0.25 | 3.29 | 0.45 | 1.06 | 0.10 | 1.01 | 0.16 |
| Cs | 0.74 | 1.00 | 1.20 | 0.31 | 0.66 | 1.00 | 1.10 |
| Ba | 785 | 250 | 640 | 1420 | 450 | 230 | 195 |
| Rb | 37.8 | 23.6 | 26.0 | 48.0 | 25.1 | 29.9 | 26.0 |
| Sr | 783.8 | 130.3 | 162.1 | 1029 | 131.8 | 133 | 155.4 |
| Pb | 4.5 | 5.4 | 4.4 | 4.4 | 6.1 | 6.9 | 7.2 |
| La | 61.1 | 10.6 | 13.1 | 65.5 | 11.5 | 17.0 | 12.6 |
| Ce | 123.0 | 24.2 | 27.5 | 132.0 | 25.7 | 36.9 | 28.6 |
| Pr | 12.90 | 2.75 | 3.56 | 15.70 | 2.86 | 4.91 | 3.44 |
| Nd | 47.7 | 12.6 | 13.6 | 59.5 | 12.5 | 19.0 | 13.7 |
| Sm | 8.43 | 3.10 | 2.93 | 9.70 | 2.93 | 3.71 | 2.85 |
| Eu | 2.51 | 0.83 | 0.83 | 3.08 | 0.73 | 0.94 | 0.74 |
| Gd | 6.30 | 3.12 | 3.34 | 6.56 | 2.56 | 3.96 | 2.74 |
| Tb | 0.97 | 0.65 | 0.56 | 0.96 | 0.55 | 0.71 | 0.49 |
| Dy | 5.33 | | 3.58 | 5.57 | 4.00 | 4.76 | 3.39 |
| Ho | 1.01 | 0.85 | 0.74 | 1.04 | 0.95 | 1.03 | 0.73 |
| Er | 2.62 | 2.54 | 2.12 | 2.49 | 2.91 | 2.96 | 2.17 |
| Yb | 1.9 | 2.48 | 2.11 | 1.78 | 2.52 | 2.89 | 2.17 |
| Y | 27 | 24 | 19 | 27 | 23 | 26 | 18 |
| Th | 6.57 | 3.04 | 2.78 | 4.47 | 3.00 | 4.21 | 3.11 |
| U | 1.15 | 0.86 | 0.68 | 0.94 | 0.77 | 0.89 | 0.81 |
| Zr | 220 | 122 | 70 | 223 | 73 | 105 | 70 |
| Hf | 5.60 | 3.20 | 2.10 | 6.12 | 2.46 | 2.95 | 2.46 |
| Nb | 66.0 | 5.9 | 3.6 | 61.0 | 5.0 | 5.1 | 5.0 |
| Sn | 6.0 | 3.4 | 2.3 | 5.2 | 2.5 | 2.1 | 2.6 |
| Mo | 2.20 | 0.71 | 0.55 | 1.90 | 0.71 | 0.46 | 0.90 |

# APPENDIX 5.

## ISOTOPIC DATA

| SAMPLE NUMBER | LATITUDE | LONGITUDE | ROCK-TYPE | LOCATION |
|---|---|---|---|---|
| 84 221 | 42° 40' S | 147° 07' E | Chilled Margin | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 216.38 m |
| 84 222 | " | " | Chilled Margin | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 219.23 m |
| 84 223 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 227.38 m |
| 84 224 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 235.24 m |
| 84 225 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 243.47 m |
| 84 226 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 250.38 m |
| 84 227 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 265.61 m |
| 84 228 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 283.08 m |
| 84 229 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 298.65 m |
| 84 230 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 315.41 m |
| 84 231 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 331.49 m |
| 84 232 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 347.45 m |
| 84 233 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 361.04 m |
| 84 234 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 379.45 m |
| 84 235 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 392.46 m |
| 84 236 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 409.53 m |
| 84 237 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 426.76 m |
| 84 238 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 434.10 m |
| 84 239 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 445.99 m |
| 84 240 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 456.18 m |
| 84 241 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 464.46 m |
| 84 242 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 475.12 m |
| 84 243 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 486.33 m |
| 84 244 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 497.55 m |
| 84 245 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 504.32 m |
| 84 246 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 516.14 m |
| 84 247 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 528.09 m |
| 84 248 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 538.05 m |
| 84 249 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 549.27 m |
| 84 250 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 559.30 m |
| 84 251 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 569.94 m |
| 84 252 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 579.13 m |
| 84 253 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 588.78 m |
| 84 254 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 598.95 m |
| 84 255 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 609.25 m |
| 84 256 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 621.10 m |
| 84 257 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 630.05 m |
| 84 258 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 641.32 m |
| 84 259 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 651.10 m |
| 84 260 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 662.11 m |
| 84 261 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 668.76 m |
| 84 262 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 681.81 m |
| 84 263 | " | " | Dolerite | Ross Borehole 1. Core samples courtesy Dept. Mines Tas. 693.12 m |
| 84 264 | 41° 39' S | 148° 06' E | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 67.69 m |
| 84 265 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 82.75 m |
| 84 266 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 97.76 m |
| 84 267 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 112.75 m |
| 84 268 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 121.75 m |
| 84 269 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 133.78 m |
| 84 270 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 142.79 m |
| 84 271 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 151.75 m |
| 84 272 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 163.81 m |
| 84 273 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 178.81 m |
| 84 274 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 187.82 m |
| 84 275 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 199.83 m |
| 84 276 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 208.81 m |
| 84 277 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 220.81 m |
| 84 278 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 229.82 m |
| 84 279 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 241.78 m |
| 84 280 | " | " | Dolerite | Fingal Borehole, GY 68. Samples courtesy Dept. Mines Tas. 253.84 m |

# APPENDIX 6.

## ELECTRON-MICROPROBE DATA

This appendix contains representative pyroxene analyses of the samples discussed in Chapter 3. A representative analysis of the fayalitic olivine preserved in sample 84-104 is also given. Plagioclase data are not included as a broad range in compositions was obtained in each section. Minerals are referred to as OPX (orthopyroxene), CPX (clinopyroxene), PIG (pigeonite) and FAY (for the fayalitic olivine).

| **SAMPLE** | **Chilled Margin** | **84-104** | **84-104** | **84-127** | **84-127** | **84-134** | **84-134** |
|---|---|---|---|---|---|---|---|
| PX-TYPE | OPX | CPX | (FAY) | PIG | CPX | CPX | PIG |
| $SiO_2$ | 53.26 | 47.12 | 29.20 | 48.74 | 49.87 | 48.70 | 48.63 |
| $TiO_2$ | 0.11 | 0.65 | 0.09 | 0.27 | 0.46 | 0.54 | 0.43 |
| $Al_2O_3$ | 1.39 | 0.79 | | 1.24 | 1.64 | 1.23 | 0.92 |
| $Cr_2O_3$ | 0.24 | 0.01 | | 0.06 | 0.04 | | |
| FeO | 9.38 | 27.90 | 67.32 | 32.52 | 19.62 | 24.92 | 33.22 |
| MnO | 0.28 | 0.65 | 1.26 | 0.48 | 0.23 | 0.38 | 0.59 |
| MgO | 30.28 | 2.24 | 1.07 | 10.61 | 11.18 | 8.83 | 9.31 |
| CaO | 2.28 | 18.60 | 0.30 | 5.40 | 16.33 | 14.77 | 6.90 |
| Total | 97.00 | 97.60 | 99.25 | 99.64 | 99.71 | 99.00 | 100.00 |
| ATOMIC PROP. | | | | | | | |
| Si | 1.935 | 1.970 | 0.991 | 1.954 | 1.937 | 1.937 | 1.954 |
| Ti | 0.003 | 0.020 | 0.002 | 0.008 | 0.013 | 0.016 | 0.013 |
| Al | 0.059 | 0.039 | | 0.059 | 0.075 | 0.058 | 0.043 |
| Cr | 0.007 | 0.000 | | 0.002 | 0.001 | | |
| Fe | 0.285 | 0.976 | 1.911 | 1.090 | 0.638 | 0.829 | 1.116 |
| Mn | 0.009 | 0.023 | 0.036 | 0.016 | 0.008 | 0.013 | 0.020 |
| Mg | 1.640 | 0.139 | 0.054 | 0.634 | 0.647 | 0.523 | 0.558 |
| Ca | 0.089 | 0.816 | 0.011 | 0.232 | 0.723 | 0.630 | 0.297 |
| Total | 4.026 | 3.983 | 3.006 | 4.021 | 4.005 | 4.005 | 4.001 |
| | | | | | | | |
| Ca | 4.4 | 41.8 | | 11.8 | 35.9 | 31.6 | 14.9 |
| Mg | 81.1 | 7.1 | | 32.1 | 32.1 | 26.2 | 28.0 |
| Fe+Mn | 14.5 | 51.1 | | 56.1 | 32.0 | 42.2 | 57.1 |

| **SAMPLE** | **84-264** | **84-264** | **84-265** | **84-265** | **84-267** | **84-267** | **84-275** | **84-275** |
|---|---|---|---|---|---|---|---|---|
| PX-TYPE | PIG | CPX | PIG | CPX | PIG | CPX | PIG | CPX |
| $SiO_2$ | 53.28 | 51.37 | 51.92 | 51.64 | 52.92 | 52.18 | 53.18 | 51.26 |
| $TiO_2$ | 0.14 | 0.36 | 0.12 | 0.25 |  | 0.12 |  | 0.28 |
| $Al_2O_3$ | 0.73 | 1.32 | 0.74 | 1.12 | 0.55 | 1.03 | 0.64 | 1.20 |
| $Cr_2O_3$ | 0.00 | 0.00 | 0.02 | 1.14 |  |  |  |  |
| FeO | 17.65 | 14.03 | 22.90 | 14.25 | 19.87 | 11.07 | 16.05 | 13.87 |
| MnO | 0.42 | 0.33 | 0.50 | 0.32 | 0.46 | 0.29 | 0.37 | 0.33 |
| MgO | 24.54 | 15.05 | 17.78 | 14.51 | 20.72 | 15.93 | 22.45 | 14.38 |
| CaO | 3.64 | 17.45 | 5.60 | 17.14 | 4.67 | 17.84 | 4.31 | 16.92 |
| Total | 100.00 | 99.94 | 99.57 | 99.25 | 99.30 | 98.46 | 97.01 | 98.24 |
| ATOMIC PROP. |  |  |  |  |  |  |  |  |
| Si | 1.952 | 1.946 | 1.978 | 1.962 | 1.986 | 1.972 | 2.003 | 1.965 |
| Ti | 0.004 | 0.010 | 0.004 | 0.007 | 0.003 | 0.004 | 0.000 | 0.008 |
| Al | 0.032 | 0.059 | 0.033 | 0.050 | 0.025 | 0.046 | 0.028 | 0.054 |
| Cr | 0.000 | 0.000 | 0.001 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 |
| Fe | 0.541 | 0.448 | 0.739 | 0.457 | 0.627 | 0.350 | 0.506 | 0.450 |
| Mn | 0.013 | 0.011 | 0.016 | 0.010 | 0.015 | 0.009 | 0.012 | 0.011 |
| Mg | 1.340 | 0.843 | 1.000 | 0.819 | 1.154 | 0.898 | 1.259 | 0.818 |
| Ca | 0.143 | 0.705 | 0.228 | 0.698 | 0.188 | 0.723 | 0.174 | 0.693 |
| Total | 4.025 | 4.023 | 3.999 | 4.004 | 3.998 | 4.001 | 3.983 | 4.000 |
|  |  |  |  |  |  |  |  |  |
| Ca | 7.0 | 35.1 | 11.5 | 35.2 | 9.5 | 36.5 | 8.9 | 35.2 |
| Mg | 65.8 | 42.0 | 50.4 | 41.3 | 58.2 | 45.4 | 64.5 | 41.5 |
| Fe+Mn | 27.2 | 22.9 | 38.1 | 23.5 | 32.4 | 18.2 | 26.6 | 23.4 |

| **SAMPLE** | **84-276** | **84-276** | **84-281** | **84-281** | **84-283** | **84-283** | **84-289** | **84-289** |
|---|---|---|---|---|---|---|---|---|
| PX-TYPE | PIG | CPX | PIG | CPX | PIG | CPX | PIG | CPX |
| $SiO_2$ | 50.81 | 52.10 | 52.69 | 50.48 | 54.32 | 52.21 | 55.33 | 53.13 |
| $TiO_2$ | | | 0.14 | 0.39 | | | 0.08 | 0.19 |
| $Al_2O_3$ | 0.58 | 1.10 | 0.77 | 1.34 | 0.42 | 1.18 | 1.07 | 1.70 |
| $Cr_2O_3$ | | | 0.03 | 0.02 | | | 0.18 | 0.20 |
| FeO | 17.33 | 11.48 | 16.26 | 14.33 | 14.95 | 13.02 | 11.09 | 7.11 |
| MnO | 0.43 | 0.30 | 0.39 | 0.33 | 0.35 | 0.31 | 0.24 | 0.19 |
| MgO | 20.62 | 16.86 | 24.68 | 15.22 | 24.64 | 15.86 | 29.48 | 19.49 |
| CaO | 4.55 | 16.18 | 4.76 | 16.82 | 4.41 | 16.50 | 2.35 | 18.47 |
| Total | 94.42 | 98.13 | 99.71 | 98.93 | 99.09 | 99.26 | 99.82 | 100.48 |
| ATOMIC PROP. | | | | | | | | |
| Si | 1.990 | 1.971 | 1.941 | 1.928 | 1.992 | 1.967 | 1.944 | 1.933 |
| Ti | 0.049 | 0.003 | 0.004 | 0.011 | 0.000 | 0.005 | 0.002 | 0.005 |
| Al | 0.027 | 0.050 | 0.034 | 0.060 | 0.018 | 0.053 | 0.044 | 0.073 |
| Cr | 0.001 | 0.000 | 0.001 | 0.001 | 0.000 | 0.000 | 0.005 | 0.006 |
| Fe | 0.561 | 0.369 | 0.503 | 0.461 | 0.459 | 0.414 | 0.327 | 0.216 |
| Mn | 0.014 | 0.010 | 0.012 | 0.011 | 0.011 | 0.010 | 0.007 | 0.006 |
| Mg | 1.209 | 0.943 | 1.353 | 0.864 | 1.346 | 0.886 | 1.609 | 1.057 |
| Ca | 0.190 | 0.655 | 0.188 | 0.688 | 0.173 | 0.666 | 0.088 | 0.720 |
| Total | 3.994 | 4.001 | 4.035 | 4.024 | 3.999 | 4.002 | 4.027 | 4.017 |
| | | | | | | | | |
| Ca | 9.6 | 33.1 | 9.2 | 34.0 | 8.7 | 33.7 | 4.4 | 36.0 |
| Mg | 61.2 | 47.7 | 65.8 | 42.7 | 67.7 | 44.8 | 79.2 | 52.9 |
| Fe+Mn | 29.1 | 19.2 | 25.1 | 23.3 | 23.6 | 21.5 | 16.5 | 11.1 |

# APPENDIX 7

## ION MICROPROBE U-Pb DATING OF ZIRCONS AND BADDELEYITES

The advantages of dating zircon separates using sensitive high mass-resolution ion microprobe (SHRIMP) mass spectrometry, compared with conventional techniques, have been demonstrated in a number of recent publications (e.g. Compston *et al.*, 1984; 1986). As well as greater ease of sample preparation (i.e. no dissolution and extraction of Pb is required), the major advantage of SHRIMP is that individual grains, and growth zones within grains can be dated separately. Whereas conventional analysis gives the average composition or age of a zircon population or crystal, SHRIMP makes it possible to date each of the several different aged components that may be present in the zircons from one rock.

It was considered that if zircons could be found in samples of Tasmanian Dolerite, this type of dating could prove extremely useful in studying these rocks. Apart from simply dating the dolerites, identification of xenocrystic zircons would give a direct indication of contamination by continental crust. There are three methods of obtaining xenocrystic zircons in magmas. First, the zircons may be introduced into the source and be incorporated into the magma during partial melting, secondly, zircons may be entrained into the magma during ascent and/or emplacement, or thirdly, after emplacement, the larger intrusions may melt and assimilate roof rocks. It is, therefore, most likely that if xenocrystic zircons from the host rocks are preserved, they will be found in the chilled margin dolerites and/or the most felsic differentiated dolerites towards the top of large intrusions. Clearly, if zircons have crystallized from the dolerite magma itself, then they are also most likely to occur in the most silicic differentiates with highest Zr content towards the top of the large intrusions.

Calculations of the zircon saturation in the chilled and silicic dolerites have been performed using the model of Watson and Harrison (1983). The results can only be treated in a general sense as their model is formulated using granitic compositions, and significant extrapolation of their results is required; however, it is apparent that the chilled margin liquids with M-values of 3.1 ($M=[Na+K+2Ca]/[Al.Si]$) and Zr contents of ~95 ppm at high temperatures (~1200°C) will not be saturated in zircon. Zircon will not crystallize from these liquids, and any xenocrystic zircon would be unstable and dissolve in the melt. It should be expected then, that the chilled dolerites would not contain zircons. It may be argued that dissolution requires time, and if contamination occurred shortly prior to quenching with little time available to permit the dissolution of the zircon, then some remnant crystals may be found (cf. Kambalda). Two chilled margin samples (for which ~1 kg of material was available) were crushed and the heavy minerals separated. The absence of zircon in these samples is consistent with the model calculations; either no contamination has occurred, or the xenocrystic zircons have been consumed by the melt.

The type of model calculations performed for the chilled margin samples are not as simple to apply to the strongly fractionated dolerites chosen from Red Hill. This is because the curves used to evaluate the zircon saturation in melts apply to the Zr concentration in the liquids at the point of saturation. In the slowly cooled differentiates, it is not clear whether zircon should begin to crystallize from a liquid of the bulk composition of this rock, or if this is more likely to occur after the crystallization of other phases.

Using the bulk compositions of samples 84-103 (273 ppm Zr) and 84-104 (334 ppm Zr) from close to the top of the Red Hill intrusion, M-values of 2.2 and 2.3 are obtained respectively. Extrapolating the results of Watson and Harrison (1983) to these values, zircon may be saturated at temperatures below approximately 750-800°C. These extrapolations may not be justified but the results indicate that zircon saturation is possible. Zircon saturation will probably become even more favourable as the Zr content of the residual liquid is increased by the crystallization of other phases in which zircon is incompatible (e.g. plagioclase).

Approximately 0.5 kg of the two samples from Red Hill were crushed and the heavy minerals separated; both samples yielded numerous zircons. The zircons are long prismatic crystals with well developed facetted terminations and are colorless to pale brown. Strong zoning occurs in many of the crystals from sample 84-103 (from the summit of Red Hill) and cores tend to be rather poorly defined. The other zircons, particularly those from sample 84-104 (~120 m lower in the intrusion) do not show strong zoning but do possess similar morphology to the rest of the population. In many of these zircons, the centre of the crystal appears to be long and hollow and is sometimes filled with a dark-brown to black material, the composition of which was not determined.

In addition to the zircons, long prismatic crystals of baddeleyite are also abundant in both samples. This is surprising as it would be expected that in siliceous melts, baddeleyite ($ZrO_2$) should react to produce zircon, $ZrSiO_4$ (e.g. Butterman and Foster, 1967; Nasland, 1987). Other occurrences of baddeleyite have been noted in interstitial Zr-enriched melt phases, which are believed to represent late-stage products of magmatic differentiation (e.g. Keil and Fricker, 1974; Williams, 1978b). Despite careful examination of thin-sections of 84-103 and 84-104, neither of the Zr-rich phases were observed. It is, therefore, not clear what the physical relationship is between these minerals and other phases in the matrix. It is possible that the baddeleyites may have formed during quenching caused by late-stage volatile release and are not products of equilibrium crystallization. Alternatively, the baddeleyites may have crystallized in the early stages of cooling when zircon was not saturated in the melt, and were subsequently enclosed in a silica-poor phase which effectively removed them from further interaction with the melt.

The baddeleyite crystals are of similar appearance to the zircons although the former are flatter in cross-section and have striations parallel to their elongation. Typical zircon and baddeleyite crystals are illustrated in Figure 7.1. Between ~30-50 grains each of zircon and baddeleyite were hand-picked from each sample and prepared for ion-probe analysis (Compston *et al.*, 1984).

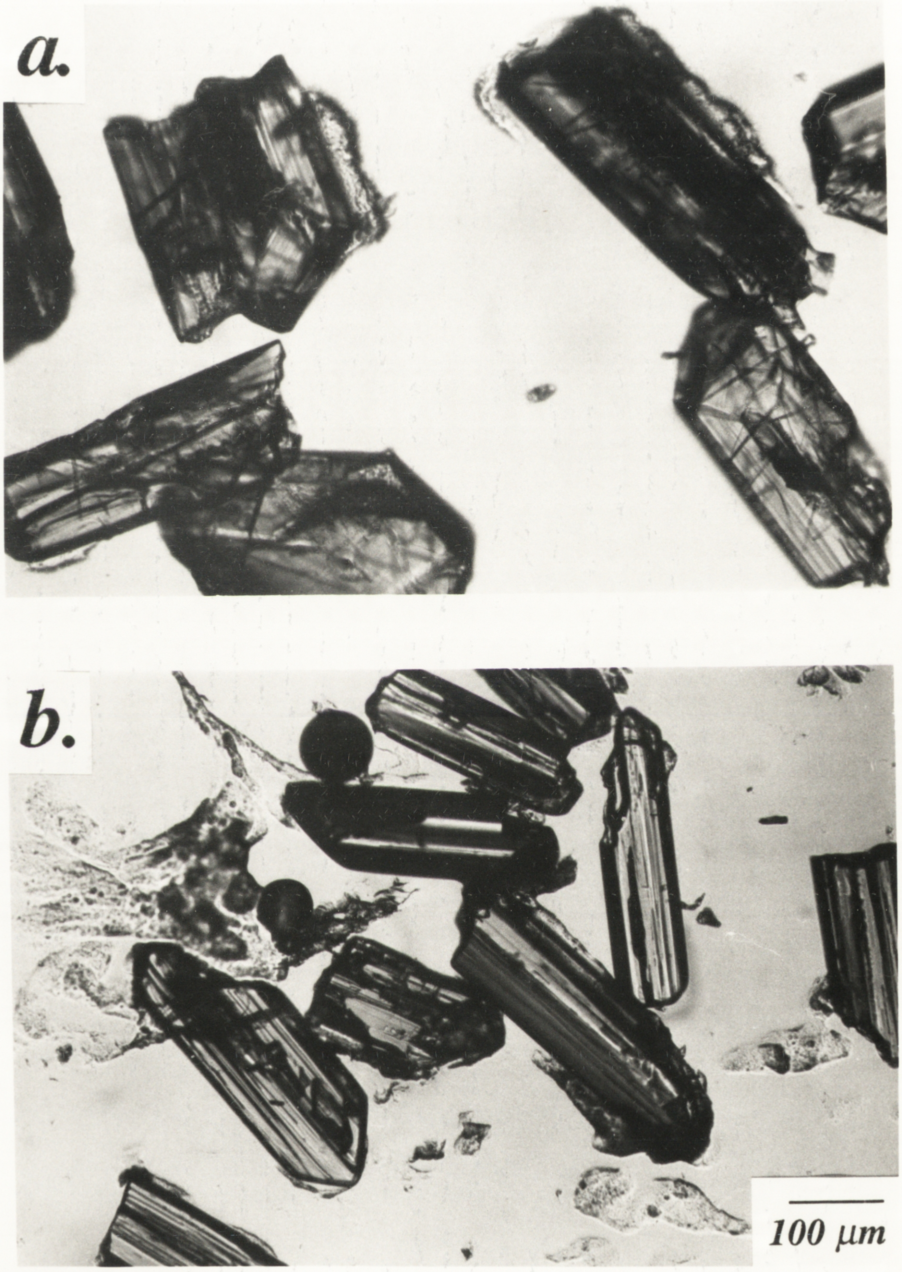


**Fig. 7.1** Photographs illustrating the morphology of typical Zr-rich phases from samples 84-103 and 84-104. **a.** Euhedral zircons (broken during crushing) showing well developed crystal terminations and fine-scale zoning. The once hollow core of the crystal in the upper left-hand side has been filled with material. **b.** Prismatic baddeleyite crystals (also broken during crushing) which appear unzoned and have characteristic striations parallel to their length.

## 7.1 AGE DATA

As relative secondary ion yields under primary ion bombardment are matrix dependent (Shimizu and Hart, 1982 and references therein), separate reference standards were required for the two minerals, and measurements of these were interspersed with analyses of the unknowns. The zircon reference used was a Sri Lankan zircon SL3, which has a concordant age of 555 Ma and $^{206}Pb/^{238}U$ ratio of 0.0894. The relationship between $Pb^+/U^+$ and $UO^+/U^+$ is such, that a plot of ln(radiogenic $^{206}Pb^+/U^+$) versus $UO^+/U^+$ is linear. Using the data from multiple analyses of SL3, these parameters were used to plot a calibration curve, and the Pb/U ratios of the unknowns were determined relative to this.

The baddeleyite standard TK-82-8, has a concordant age of 1135 Ma and a $^{206}Pb/^{238}U$ ratio of 0.1921. The calibration curve for this mineral is based on ln(radiogenic $^{206}Pb^+/UO^+$) versus $UO_2^+/UO^+$. Although linear, this curve is much steeper than that of the zircon reference, and therefore determinations of Pb/U from $UO_2^+/UO^+$ are much more prone to uncertainty. The Pb/U of the baddeleyite unknowns were determined by using the value of radiogenic $^{206}Pb^+/UO^+$ determined from the curve, and the known Pb/U ratio of TK-82-8.

Corrections have been made for common lead assuming a Broken Hill Pb isotopic composition. The precisions of the zircon analyses were determined almost entirely by counting statistics (Compston *et al.*, 1984) and have been calculated using a computer program developed at the ANU. Unfortunately this program cannot be applied to the baddeleyite data and these have not been assigned individual analytical uncertainties. Instead, duplicate measurements of individual baddeleyite crystals indicate that the ages obtained for the entire data set can be considered to be equivalent to within error (see discussion below).

Analyses were obtained for 11 zircons and 14 baddeleyites including multiple analyses on individual grains (Table 7.1). The $^{206}Pb/^{238}U$ data corrected for common Pb using $^{208}Pb$ (Compston *et al.*, 1984) have been chosen for the zircons as this peak is large and less prone to errors in counting statictics. The zircons are concordant within analytical uncertainty (Fig. 7.2). Even though the very high radiogenic Pb content of the grains makes the determination of radiogenic $^{207}Pb$ relatively precise, the very small variation in $^{207}Pb/^{206}Pb$ is a function of time for very young materials (i.e. $^{207}Pb/^{206}Pb$ differs from 0 to 180 Ma by only ~8%), and $^{207}Pb/^{206}Pb$ is a very imprecise means of determining the zircon age. The Pb/U ratio, although determined with less precision, is a more sensitive measure of age.

The pooled mean $^{206}Pb/^{238}U$ age of 8 spots measured from sample 84-103 is 185.7 Ma, with an observed $1\sigma_{mean}$ of 1.6 Ma. This is marginally greater than the standard error expected from the precision of individual determinations ($F = 2.2$ cf. $^7F_\alpha = 2.01$) and there are no outliers, which almost certainly indicates that the value of 1.76% for the uncertainty in the $^{206}Pb/^{238}U$ of the standard was a slight underestimate. The best estimate of the age of 84-103 is therefore 185.7 ± 1.6Ma.

Only three measurements were made of zircons from sample 84-104. These also are concordant within the analytical uncertainties. The mean $^{206}Pb/^{238}U$ age of the zircons is 172.7 Ma. The observed $1\sigma_{mean}$ is 0.9 Ma, significantly less that that expected form the precision of the individual analyses (1.7 Ma). The best estimate of the age of 84-104 is therefore 172.3 ±

U-Pb data obtained by SHRIMP analysis of zircon and baddeleyite separates from two silicic differentiates of the Red Hill Dyke.

| Sample, grain-spot | $^{206}$Pb/$^{238}$U ± 1σ | $^{207}$Pb/$^{235}$U ± 1σ | Age (Ma) ± 1σ |
|---|---|---|---|
| ZIRCONS | | | |
| 84-103/1-core | 0.0301±5 | 0.206±5 | 191±3.5 |
| 84-103/2-rim | 0.0308±5 | 0.211±5 | 193±3.5 |
| 84-103/2-core | 0.0295±5 | 0.194±4 | 188±3.5 |
| 84-103/3-core | 0.0284±5 | 0.201±6 | 181±3.0 |
| 84-103/4-core | 0.0296±5 | 0.204±4 | 188±3.5 |
| 84-103/5-rim | 0.0288±5 | 0.196±5 | 183±3.0 |
| 84-103/5-core | 0.0288±5 | 0.194±5 | 183±3.0 |
| 84-103/6-rim | 0.0285±5 | 0.194±5 | 181±3.0 |
| 84-104/1-core | 0.02696±5 | 0.177±6 | 171±3.0 |
| 84-104/2-core-rim | 0.0271±5 | 0.194±6 | 173±3.0 |
| 84-104/3-core | 0.0274±5 | 0.186±5 | 174±3.0 |
| BADDELEYITES | | | |
| 84-103/1-1 | 0.034 | -0.396 | 179 |
| 84-103/2-1 | 0.027 | -0.022 | 178 |
| 84-103/3-1 | 0.022 | -0.096 | 164 |
| 84-103/4-1 | 0.024 | 0.048 | 191 |
| 84-103/5-1 | 0.029 | 0.184 | 170 |
| 84-104/1-1 | 0.024 | 0.012 | 215 |
| 84-104/2-1 | 0.025 | 0.145 | 176 |
| 84-104/3-1 | 0.028 | 0.222 | 148 |
| 84-104/3-2 | 0.026 | 0.208 | 186 |
| 84-104/4-1 | 0.028 | 0.246 | 156 |
| 84-104/5-1 | 0.029 | 0.056 | 186 |
| 84-104/6-1 | 0.025 | -0.161 | 158 |
| 84-104/7-1 | 0.030 | 0.281 | 156 |
| 84-104/7-2 | 0.026 | 0.091 | 175 |

1.7Ma. The difference between the two mean ages is significant at the 1% level (i.e. the difference between the means, divided by the standard error of the differences is 11.5).

The ages quoted for the baddeleyites are based on $^{204}$Pb corrected $^{206}$Pb/$^{238}$U data. Despite attempts to reduce the uncertainties in the ages obtained for the baddeleyites, there is a large amount of variation within each rock sample, and even within individual crystals (Table 7.1). More development work on the baddeleyite technique is required. Because of the large uncertainties, the baddeleyites from 84-103 and 84-104 are considered to be of the same age and average estimates from the two samples compare well.

The ages obtained for the two populations of zircons and the averaged baddeleyite results (185.7 ± 1.6 Ma, 172.7 ± 1.7 Ma and 174.1± 4.5 Ma respectively), are generally consistent with previous K-Ar dates obtained for this intrusion (174 ± 5 Ma; Schmidt and McDougall, 1977; recalculated using the recommended decay constants of Steiger and Jäger, 1977), and a Rb-Sr isochron age of 180± 13 Ma obtained in this study (Fig. 7.3).

Although the baddeleyite data, and zircon results from sample 84-104 are very similar to the K-Ar age, it is not clear why the zircons in sample 84-103 should appear significantly older. It is important to note that these data are consistent with the crystallization of these Zr-rich phases directly from the fractionated magmas. None of the zircon cores show any indication of being xenocrystic. These data support the contention that the silicic rocks towards the upper levels of the Red Hill Dyke are true magmatic differentiates and do not represent metasomatised roof rocks (McDougall, 1962; Chapter 3); therefore, the discrepancy in the age of sample 84-103 remains enigmatic.

**Table 7.1** U-Pb age data (in Ma) obtained by SHRIMP analysis of zircon and baddeleyite separates. The mineral separates have been extracted from two silicic differentiates from the Red Hill Dyke in southern Tasmania. Repeat analyses of grains are given in parentheses (in the case of the zircons the rim analyses are listed first and the data for the cores are given in parentheses).

| | 84-103 | | 84-104 | |
|---|---|---|---|---|
| | Zircon ± 1σ | Baddeleyite | Zircon ± 1σ | Baddeleyite |
| | 191±3.5 | 179 | 171±3.0 | 215 |
| | 193±3.5 (188±3.5) | 178 | 173±3.0 | 176 |
| | 181±3.0 | 164 | 174±3.0 | 148 (186) |
| | 188±3.5 | 191 | | 156 |
| | 183±3.0 (183±3.0) | 170 | | 186 |
| | 181±3.0 | | | 158 |
| | | | | 156 (175) |
| Average ± 1$\sigma_{mean}$ | 185.7± 1.6 | 176.4 ± 4.1 | 172.7± 1.7 | 172.9 ± 6.6 |

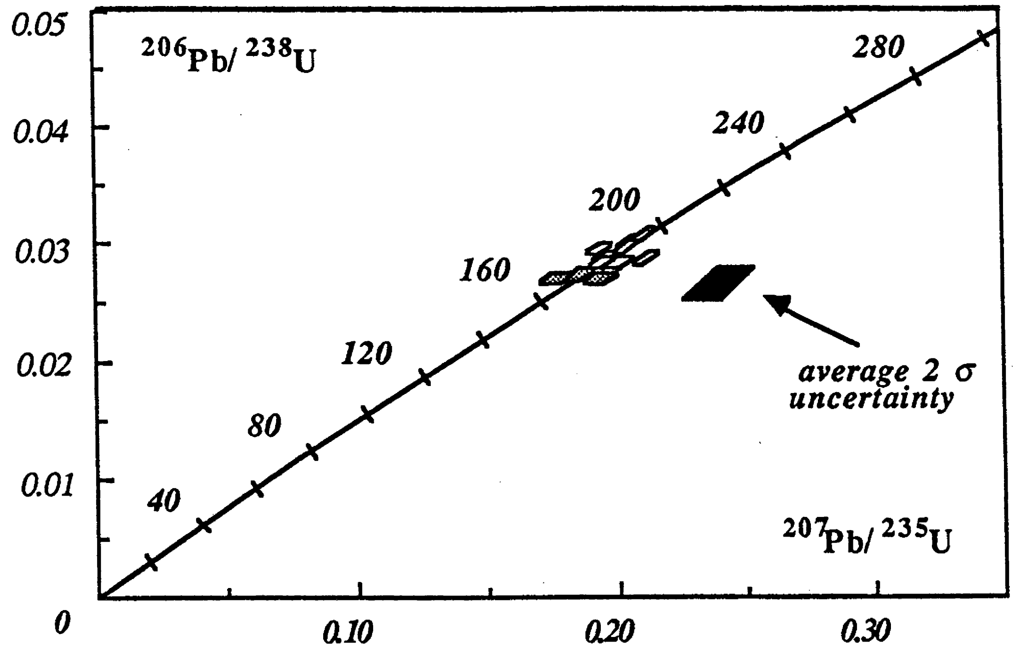


Fig. 7.2 Concordia diagram illustrating the results of the zircon analyses. The symbols correspond to the data for 84-104 (shaded), and 84-103 (open). The data are plotted as 1σ error-boxes and an estimate of the average 2σ uncertainty is included for comparison.

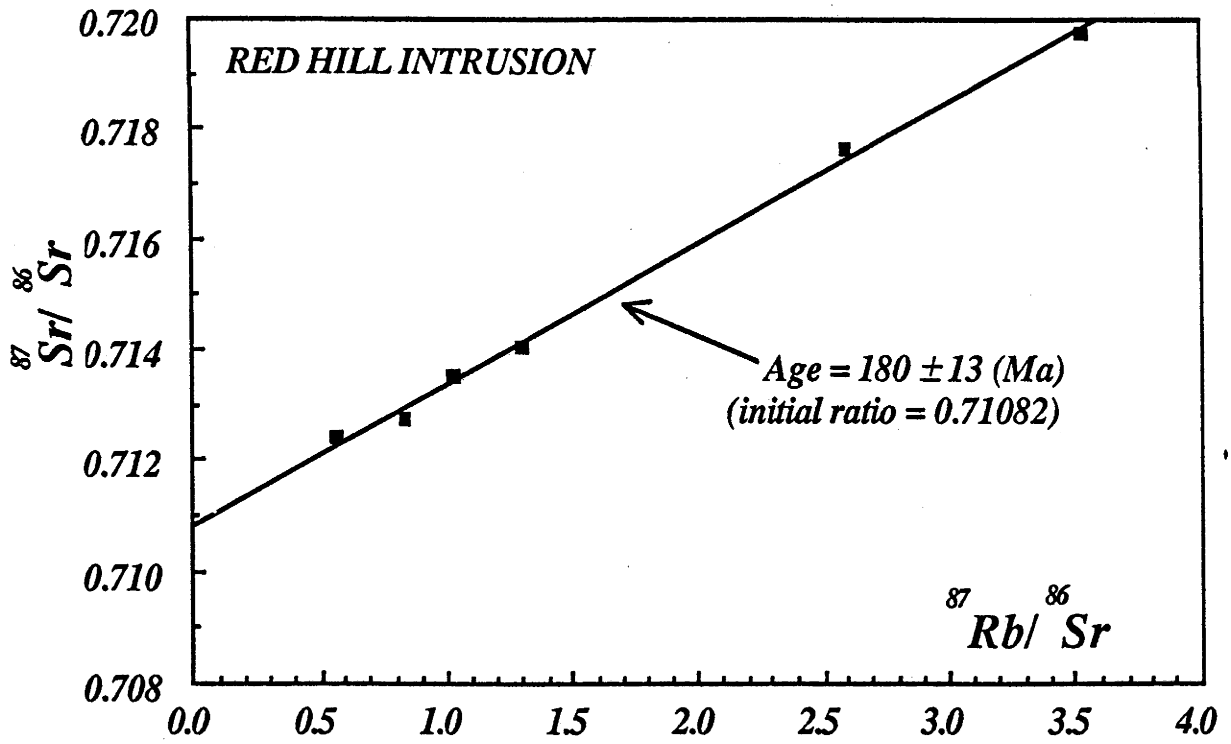


Fig. 7.3 Rb-Sr isochron diagram showing the regression of data from Red Hill (data from Appendix 5). Although the Model 1 regression gives an age of 178.5 ± 1.5 Ma, the MSWD is 52 indicating that the scatter in the data is beyond the analytical precision. The Model 3 fit of 180 ± 13 Ma is therefore preferred.

## 7.2 CONCENTRATION DATA

In addition to the age data, the concentrations of U, Th and Pb in the zircons are also of interest. The data for both samples are presented in Table 7.2 and indicate that the zircons have unusually high U and Th contents. Zircons from granitic rocks have been shown to contain U and Th contents generally in excess of 300 and 100 ppm respectively (Ahrens, 1965; Speer, 1980). Of the granitic zircons studied by Ahrens (1965) average concentrations of U (1330 ppm) and Th (630 ppm) were obtained, and less than ~5% of the zircons had concentrations of U>4000 ppm and Th>2000 ppm. Ion-probe analysis shows that even in the zircons from one rock, differences in U and Th content of two orders of magnitude are not unusual.

**Table 7.2** U, Th and Pb concentrations in the zircons measured from samples 84-103 and 84-104. All concentrations are in ppm. f% is the amount of Pb originally in the crystal (prior to radioactive decay of U) expressed as a percentage of the total Pb present.

| Sample/Grain | U | Th | Pb (total) | Th/U | f% |
|---|---|---|---|---|---|
| 84-103/1 core | 4989 | 3699 | 167 | 0.74 | 0.60 |
| 84-103/2 rim | 7093 | 6070 | 251 | 0.86 | 0.80 |
| 84-103/2 core | 5089 | 4354 | 175 | 0.86 | 0.57 |
| 84-103/3 core | 3620 | 4673 | 131 | 1.29 | 0.76 |
| 84-103/4 core | 6740 | 4965 | 224 | 0.74 | 0.89 |
| 84-103/5 rim | 5966 | 3923 | 194 | 0.66 | 4.12 |
| 84-103/5 core | 4746 | 4163 | 161 | 0.88 | 3.11 |
| 84-103/6 rim | 4697 | 5106 | 164 | 1.09 | 2.44 |
| 84-104/1 core | 2299 | 2178 | 75 | 0.95 | 4.00 |
| 84-104/2 core-rim | 2081 | 1995 | 68 | 0.96 | 2.94 |
| 84-104/3 core | 2930 | 1585 | 87 | 0.54 | 3.45 |

The very high concentration of U and Th in these zircons is particularly interesting as they have crystallized from the silicic differentiates of mafic magmas. It is not clear why the zircons from 84-104 have significantly lower U and Th (and therefore Pb) contents. Although the bulk rock U content of 84-104 is lower than that of 84-103 (i.e. 3.1 ppm cf. 5.2 ppm), the Th content is actually higher in 84-104 (i.e. 11.2 ppm cf. 9.7 ppm).

Ahrens (1965) noted that although the Th/U ratios in granitic rocks is about 3-4, the ratios in the zircons from granites is typically less than 1 and commonly between ~0.2 and 0.6. The Th/U ratios in the zircons from samples 84-103 (bulk rock Th/U=1.9) and 84/104 (bulk rock Th/U=3.6) vary between 0.54 and 1.29 with most falling above 0.85 (Table 7.2). There is no difference observed in this parameter between the two rock samples; that is, the lower concentrations of Th and U in zircons from 84-104 are not reflected in a change in the Th/U ratio.

## 7.3 SUMMARY

The only zircons (and baddeleyites) obtained from the Tasmanian Dolerites occur in the most silicic differentiates from the Red Hill Dyke. These have not been identified in thin-section and it is not clear where they occur in the rock matrix. The ages obtained on single crystals of zircon and baddeleyite from two samples are similar to those reported for the age of the intrusion obtained by K-Ar dating (Schmidt and McDougall, 1977). These Zr-rich phases crystallized from silicic differentiates of the dolerite magma and there is no evidence to suggest that any of the roof rocks were assimilated. The lack of zircon in the chilled dolerites does not rule out contamination of the dolerite magma (or its source), because zircon is not saturated in the chilled margin liquid compositions and would therefore react with the melt.

# APPENDIX 8.

## ESTIMATE OF THE MAGMA TEMPERATURE AT THE TIME OF INTRUSION

The low abundance of microphenocrysts in the chilled margin dolerites and the relatively uniform whole-rock geochemical compositions, indicate that these rocks may closely approximate quenched liquids. On this assumption, three samples were selected for 1 atmosphere melting experiments using a Mo-strip heater. The experiments were carried out in an Ar atmosphere to avoid oxidation, and the temperatures were determined with an optical pyrometer. The pyrometer was calibrated using multiple runs of two synthetic basalt compositions of known melting temperature. The correction due to emissivity is between 60 and 70°C which immediately introduces an error of ~10°C. The three samples chosen have slightly different MgO contents (6.84 wt%, 6.66 wt% and 6.08 wt%) but show no range in melting temperature outside the estimated analytical uncertainty (~30°C). The six runs performed give a total range from 1225 to 1255°C with an average value of 1230°C. Although this technique is a rather rough way of determining the melting point of rock samples, it provides reasonable constraints within the errors cited. If the powders used in the melting tests lose their volatiles during heating (which is likely), the estimate of ~1230°C (±~30°C) for the Tasmanian chilled dolerites will be based on anhydrous conditions and must be considered an upper limit.

Using anhydrous 1 atm phase equilibria calculations (based on the models of Nielsen and Dungan, 1983; and Glazner, 1984) temperatures of between 1190 and 1205°C for liquidus plagioclase are calculated from the average chilled margin whole-rock composition. Also, using the equations for low-Ca pyroxene from Nielsen and Dungan, a liquidus temperature of ~1200°C is calculated. These results are consistent with the experimental determination obtained.

Finally, the crystallisation temperature of orthopyroxene in the chilled margins has been calculated using the model of Lindsley (1983). At pressures between ~1 atm and 10 kbar, the temperatures obtained are ~1250 ± ~50°C.

The three independent methods used to determine the approximate temperature of the magmas at the time of intrusion have given generally consistent results. Simple melting experiments give a maximum temperature of ~1230°C (±30°C); anhydrous 1 atm phase equilibria calculations indicate temperatures between ~1190-1200°C (±~30°C); and pyroxene thermometry indicates values of ~1250°C (±~50°C). It is concluded that the best estimate of the temperature of the intruding magma is probably close to ~1200°C.