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Supporting Online Material for

A Vestige of Earth's Oldest Ophiolite

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Supporting Online Material

Plagiogranites: A plagiogranite is a rock composed mainly of Na-rich plagioclase and quartz, with minor amphibole and/or biotite. It is a subordinate rock type commonly found in ophiolite complexes as patches and lenses associated with gabbro and sheeted dikes. Plagiogranites may form as a result of fractional crystallization from a basaltic magma, or by partial melting of gabbro in water-saturated shear zones (*S1*).

X-ray fluorescence spectrometry (XRF): Major- and trace-element analyses were performed by X-ray fluorescence spectrometry at the University of Bergen, Norway. The glass bead technique (*S2*) was used for the major elements, and powder pellets for the trace elements, employing international basalt standards with the recommended or certified values (*S3*) for calibration.

O-isotopes: Whole-rock powers were reacted with BrF_5 at 625ºC to liberate oxygen (*S4*). Oxygen was converted to CO_2 and analysed for isotopic ratios on a Finnigan-MAT 252 mass spectrometer at University of Alberta (Edmonton, Canada). The data are reported in the standard delta notation with respect to SMOW (Standard Mean Ocean Water) (*S5*) using a water/CO_2 fractionation factor of 1.0407 to ensure compatibility of these data with previous studies of mid-ocean ridge rocks. Analytical reproducibility was ±0.1‰.

Further comments to the δ^{18}O: The oxygen isotope composition of the ISB pillow lavas and dikes (Table 1) do not show the same wide range as reported from Phanerozoic ophiolites (*S6-S10*) and *in-situ* oceanic crust (*S11, S12*). It is important to note that even though smaller, the observed heterogeneity of δ^{18}O shows that the putative isotopic contrast between pillows and dikes has not been overprinted by subsequent deformation and metamorphism. However, interpretation of our ISB isotope data should consider three key points. 1) We only have data from pillow lavas and dikes, from stratigraphic (in the pillow lava sequence) and pseudostratigraphic (in the sheeted dike complex) positions that at this stage cannot be constrained due to the currently unresolved structural relationships between pillows and sheeted dikes and due to the isolated nature of many outcrops within the pillow and sheeted dike units. Thus, if the original distance between our sampled pillows and dikes originally was short, one would not expect much of a variation in the primary isotopic composition arising from hydrothermal alteration. 2) The observed oxygen isotopic range is further limited because we lack data from the gabbros and ultramafics. 3) It is impossible to determine the effects of water-rock exchange because we do not know the temperature of the Early Archean ocean water. If the Archean seawater was hotter than today, as proposed by some authors (e.g. *S13*), then weathering imposes less of a delta 18-O increase. If the delta 18-O of seawater were +1 to +2 (allowed by models of K. Muehlenbachs) then our dike data fits well with hydrothermal systems that were ca. 350ºC.

Pillow lava – dike relationships: The deformation fabrics of the ISB offer some information that may help us understand some of the structural relationships of individual units and their relationships to each other. We have not observed that the dikes are folded. In contrast, associated sediments which are often interlayered with pillow lavas at many localities throughout the ISB (e.g. *S14,* and our own observations), are frequently folded. The dikes tend to be parallel to the subvertical schistocity of the complex, and Nutman (*S14*) has shown that the bedding of pillows is perpendicular to the schistosity. Overall, these spatial relationships suggest that the dikes are at a steep angle (>45°) to the bedding of the folded sediments and the bedding of the pillow lavas, as typically found in well preserved ophiolites.

Legends to Figures S1-S4

Figure S1. (**A**) Main outcrop area of the mixed dike/volcanics complex (location 2 in Fig. 1C). The location of Fig. 2C and D is in the middle left part of the photo. (**B**) Well-defined dikes with intervening layers of strongly foliated volcanic material.

Figure S2. (**A**) Main outcrop area for the 100% sheeted dike complex (location 3 in Fig. 1C). The length of the continuous exposure of dikes across the central part of the photo is ~30 m. The photos (**B**) through (**F**) of Figure S2 are all from this area. (**B**) The margins of a ~50 cm thick dike (in the middle of the photo) are sharp and well-defined. Note the extensive glacial deposits behind the exposure in the background. (**C, D, E**) Several parallel dikes with sharp, well-defined margins. (**F**) Close-up of a dike (in the middle of photo) showing distinct chilled margins.

Figure S3. Strongly deformed metagabbro from the southernmost part of the western arm of ISB (Fig. 1C).

Figure S4. Phase layering in massive ultramafic complex, east of localities 1-3 of Fig. 1C. Contact between the ultramafics and amphibolites is poorly exposed and assumed to be tectonic. The ultramafics are highly deformed and metasomatised (carbonated) to talc-magnesite schists and serpentinites, in which little original igneous mineralogy is preserved. The layering is defined by differences in both grain-size and original modal mineralogy, and ranges from dunite, lherzolite to harzburgite.

Table S1. Major and trace element analyses of pillow lava, dikes, and plagiogranite from the Isua Supracrustal Belt.

Sample #	Rock	Location (Fig. 1C)	SiO_2	TiO_2	Al_2O_3	Fe^{tot}	MnO	MgO	CaO	Na_2O	K_20	P_2O_5	L.O.I	SUM
1A2-IG-06	PL	1	54.03	0.83	15.47	11.89	0.20	5.48	7.46	3.78	0.43	0.08	0.46	100.11
1B4-IG-06	PL	1	56.78	0.76	14.63	11.07	0.19	4.95	6.97	3.84	0.31	0.07	0.35	99.92
2A-IG-06	PL	1	53.54	0.85	15.15	10.76	0.18	5.25	7.93	4.23	0.15	0.09	0.89	99.02
2B2A-IG-06	PL	1	56.54	0.84	14.01	12.04	0.17	5.66	6.62	3.71	0.16	0.06	0.25	100.06
3A2A-IG-06	PL	1	54.82	0.80	14,21	12.37	0.18	5.69	6.63	4.69	0.16	0.06	0.22	99.83
7-IG-06	Dike	3	48.26	0.50	7.19	13.31	0.24	18.66	8.49	0.51	0.05	0.02	2.54	99.77
8-IG-06	Dike	3	49.54	0.62	9.13	13.02	0.23	13.51	10.97	1.12	0.17	0.04	0.62	98.97
9-IG-06	Dike	3	50.81	0.59	8.00	12.45	0.20	15.10	9.37	1.14	0.33	0.04	0.81	98.84
16A-IG-06	Dike	3	49.11	0.42	5.80	12.73	0.22	20.46	7.44	0.42	0.03	0.02	3.12	99.77
16C-IG-06	Dike	3	50.98	0.61	8.26	12.09	0.21	14.81	9.77	1.22	0.23	0.04	0.85	99.07
16E-IG-06	Dike	3	50.00	0.49	6.20	12.82	0.23	17.27	9.77	0.67	0.39	0.02	1.05	98.91
16G-IG-06	Dike	3	48.84	0.59	7.91	12.76	0.20	15.06	11.41	0.93	0.12	0.04	0.84	98.70
17A-IG-06	Dike	3	50.91	0.62	8.30	12.16	0.20	14.71	9.57	1.48	0.24	0.04	0.87	99.10
17B-IG-06	Dike	3	49.82	0.55	7.28	12.01	0.19	16.27	11.57	0.83	0.16	0.03	0.88	99.59
10-IG-06	PG	2	68.77	0.80	15.56	3.41	0.05	1.19	2.94	6.88	0.47	0.13	0.68	100.88

Sample #	V	Cr	Co	Ni	Cu	Zn	Rb	Sr	Y	Zr
1A2-IG-06	183	76	48	57	12	129	20	140	21	85
1B4-IG-06	173	83	46	53	11	117	11	137	20	79
2A-IG-06	204	79	43	58	111	88	n.d	147	20	86
2B2A-IG-06	207	81	52	59	71	100	n.d	117	20	84
3A2A-IG-06	206	73	48	60	12	99	n.d	110	21	82
7-IG-06	126	2232	99	852	6	129	n.d	17	14	49
8-IG-06	152	1303	77	358	14	110	5	181	15	60
9-IG-06	115	1463	81	631	34	101	20	221	11	55
16A-IG-06	100	1474	101	1261	139	119	n.d	17	13	43
16C-IG-06	118	1459	76	511	120	106	11	251	16	58
16E-IG-06	107	1316	89	829	35	115	29	28	11	54
16G-IG-06	119	1475	86	780	60	117	n.d	76	17	64
17A-IG-06	120	1482	79	519	40	98	11	242	14	59
17B-IG-06	97	1369	81	718	8	97	6	32	14	63
10-IG-06	35	14	13	14	50	37	54	223	20	221

Explanation : Fe^{tot} = total iron as Fe_2O_3; L.O.I. = loss on ignition; PL = pillow lava; PG = plagiogranite; n.d =not detected; major oxides (SiO_2, TiO_2, etc.) are reported in weight percentage (wt. %); trace elements (V, Cr, etc.) are reported in parts per million (ppm).

References and notes

S1. R. B. Pedersen, J. Malpas, *Contrib. Mineral. Petrol.* **88**, 36 (1985).

S2. T. Padfield, A. Gray, *NV Philips, Eindhoven, Analytical Equipment FS* **35** (1971).

S3. K. Govindaraju, *Geostand. Newslatt. Spec. Issue* **18** (1994).

S4. R. N. Clayton, T. K. Mayeda, *Geochim. Cosmochim. Acta* **27**, 43 (1963).

S5. H. Craig, *Science* **133**, 1833 (1961).

S6. P. Agrinier, M. Javoy, J. Girardeau, *Chem. Geol*. **71**, 313 (1988).

S7. D. S. Stakes, H. P. Taylor, Jr., *J. Geophys. Res*. **97**, 7043 (1992).

S8. C. Holmden, K. Muehlenbachs, *Science* **259**, 1733 (1993).

S9. P. Schiffman, B. M. Smith, *J. Geophys. Res*. **93**, 4612 (1988).

S10. H. Fonneland-Jorgensen, H. Furnes, K. Muehlenbachs, Y. Dilek, *The Island Arc* **14**, 517(2005).

S11. K. Muehlenbachs, *Chem. Geol*. **145**, 263 (1998).

S12. J. C. Alt, K. Muehlenbachs, J. Honnorez, *Earth Planet. Sci. Lett*. **80**, 217 (1986).

S13. L. P. Knauth, D. R. Lowe, *Geol. Soc. Am. Bull*. **115**, 566 (2003).

S14. A. P. Nutman, *Elements* **2**, 223 (2006).

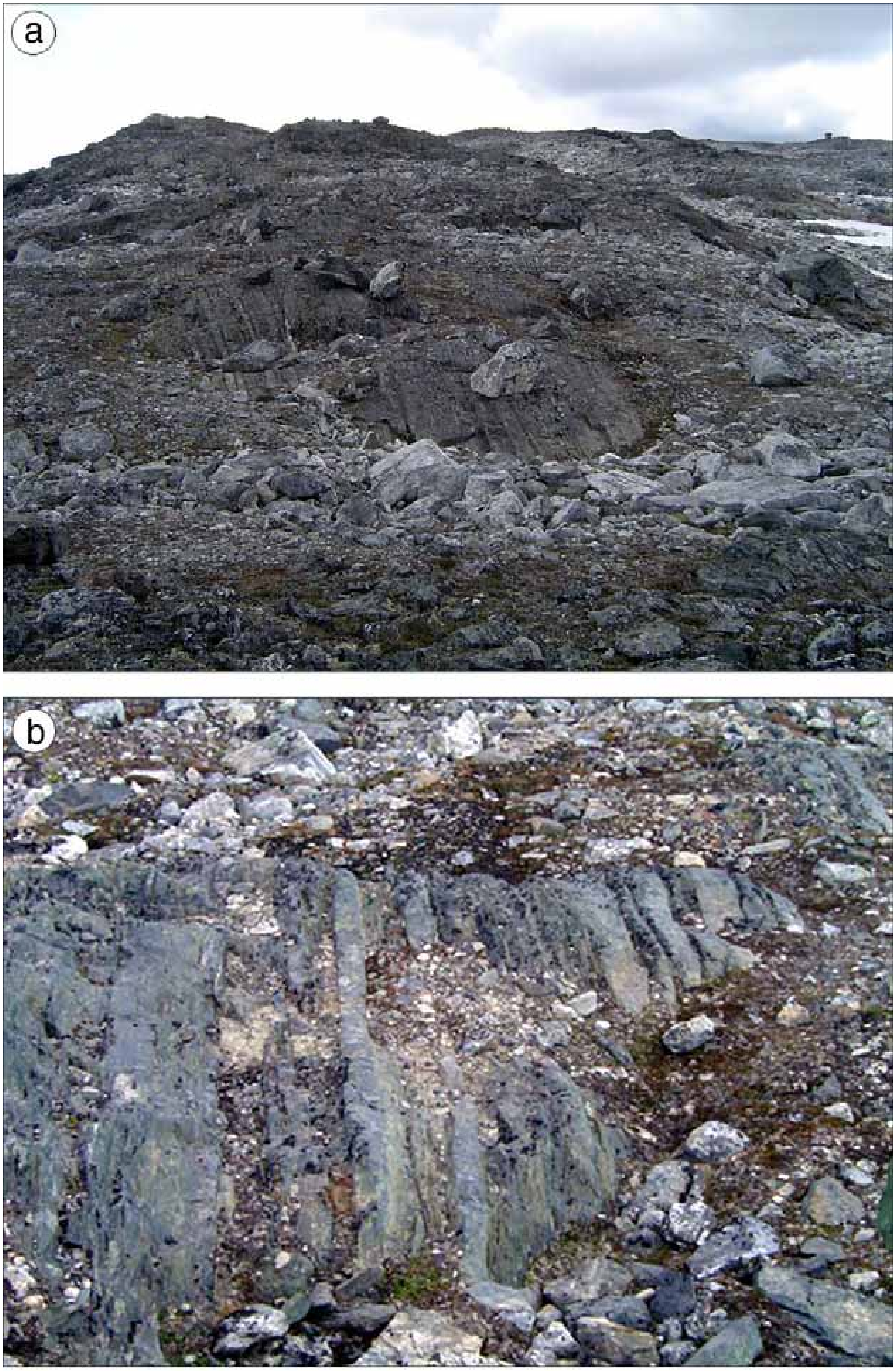

Fig. S1

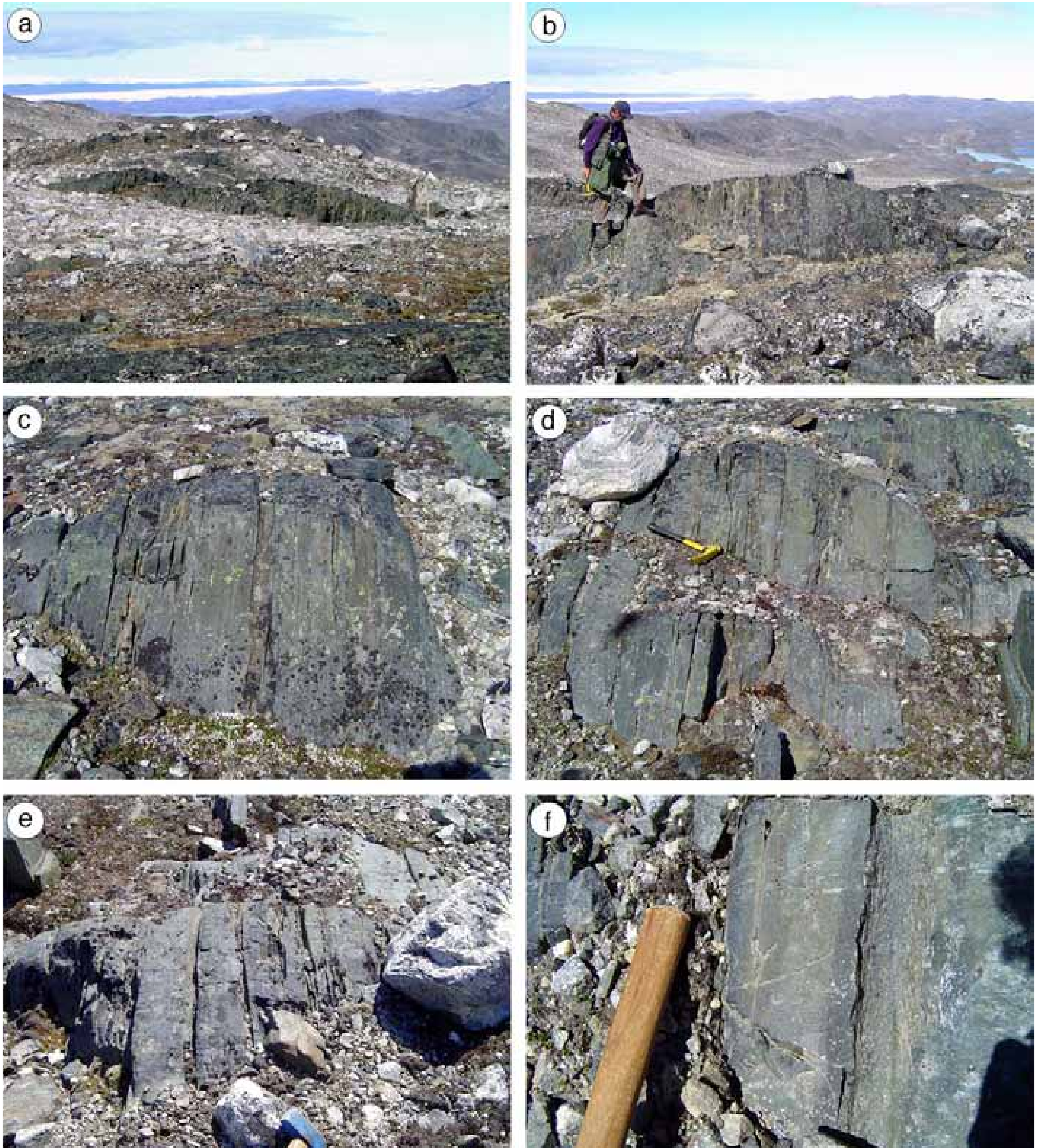

Fig. S2

Fig. S3

Fig. S4