Supplementary material for

FLATTENING THE BHUTAN HIMALAYA

Stacey L. Corrie , Matthew J. Kohn, Nadine McQuarrie, and Sean P. Long

SUPPLEMENTAL FIGURE CAPTIONS

Fig. S1. Composition maps of garnets showing representative trends. Most garnets show core-rim decreases in Mn and increases in Mg, consistent with preservation of prograde chemical zoning. Compositional reversal on rim of structurally lowest GH rock reflects retrograde reequilibration. Calcium zoning in sample BU08-95 probably reflects kinetic limitations to Ca transport in the matrix rather than change to P and T (see Kohn, 2004, for further discussion of analogous zoning patterns and P-T path calculations). Compositions correspond to spot in garnet interior (rim compositions are in supplemental file). Scale bars are all 1 mm.

Fig. S2. Plane-polarized light photomicrographs of garnet textures in the Shemgang region of Bhutan, emphasizing textural relation of internal fabric preserved by inclusions in garnet and external fabric formed by micas and shape-preferred orientation of quartz and feldspar. Distances in km represent the structural distance to the contact between the Chekha Formation and Greater Himalayan Sequence. (A) Well-developed crenulation cleavage is warped around garnet porphyroblast. Garnets exhibit inclusion-rich cores, but orientation of internal fabric is unclear. (B) Internal fabric mimics crenulations whose (former) cleavage is at high orientation to external foliation. Black horizontal stripe is a scratch. (C and D) Internal fabric smoothly varies orientation and is truncated at garnet margins by external foliation. Some garnets are elongate, possibly due to dissolution on upper and lower margins adjacent to foliation. (E) Fibrolitic sillimanite occurs locally on plagioclase grain boundaries. (F) Internal fabric in core of garnet is at angle to external fabric. Yellow inclusions of staurolite occur in NW quadrant of large garnet.

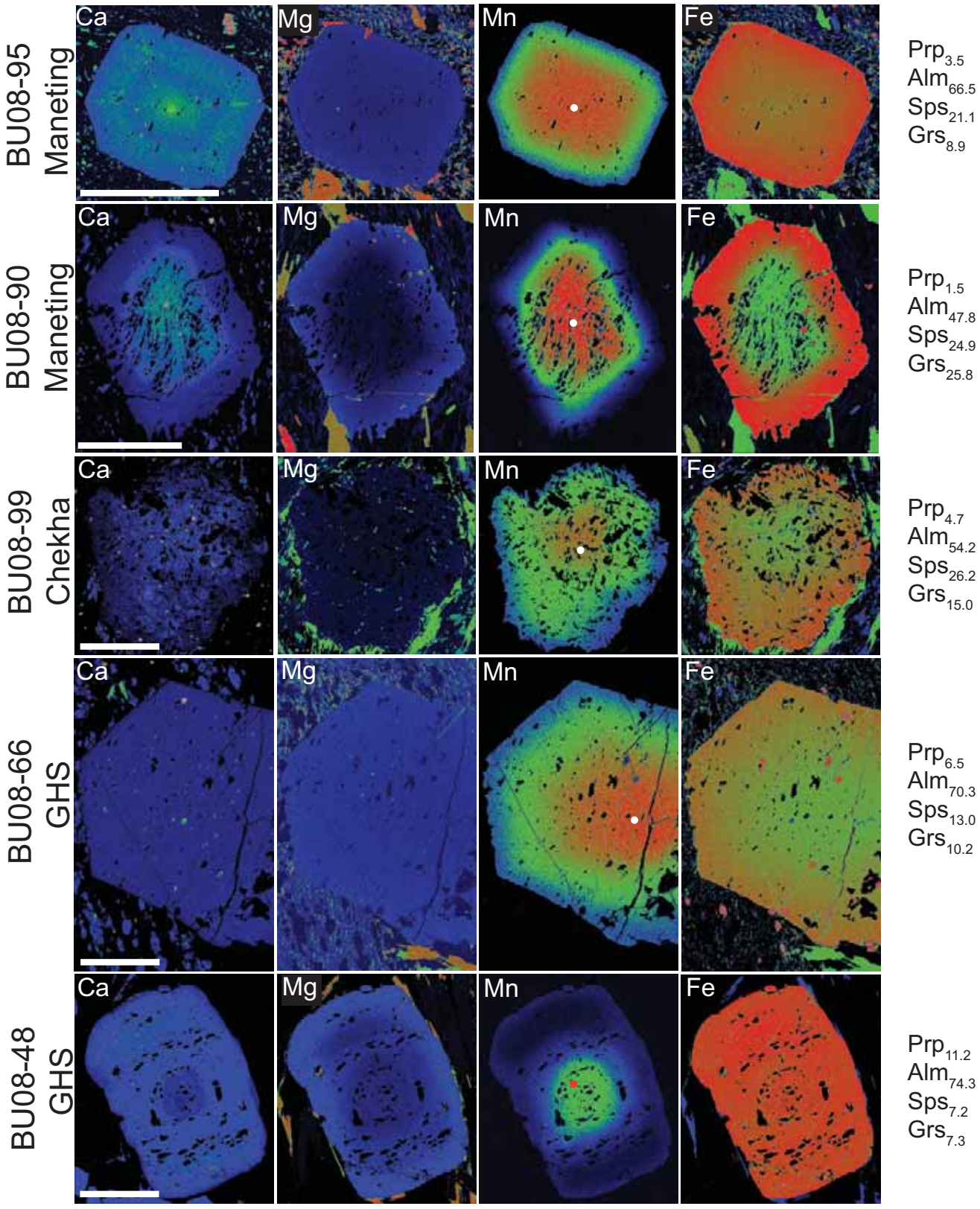
SUPPLEMENTAL DISCUSSION OF TEXTURES AND ASSEMBLAGES

Textures of rocks in the Shemgang region are documented extensively by Long and McQuarrie (2010), specifically for samples BU08-47, -48, -52, -54, -66, -75, -76, -78, -84, -88, -90, -93, and -110. Here, we discuss more generally the textural relationship of garnets to the matrix foliation, as well as some phase equilibrium constraints (Fig. S2). In this discussion, we refer to fabrics preserved by inclusion trails in the garnet as the "internal foliation" and the dominant foliation in the matrix as the "external foliation." In general, the external foliation postdates formation of garnet. Many garnets exhibit internal fabrics at an angle to the external foliation and/or truncated by that foliation at the garnet margin (Fig. S2B, C, D, F). Many garnets are additionally elongate with their short dimension sub-perpendicular to the external foliation (Fig S2C, D). In some instances, garnets exhibit asymmetric pressure-shadows or rotations of the internal foliation with respect to the external foliation (Fig. S2A-C; see also Long and McQuarrie. 2010, who first documented these textures and interpret shear senses). In some instances, a strongly differentiated crenulation cleavage is apparent in garnet cores, but at a wholly different orientation than the external foliation (Fig. S2B). We interpret these textures to indicate that the latest deformation postdates garnet growth. This interpretation is consistent with

our conclusion based on P-T data that flattening of the Shemgang section by c. 50% and formation of matrix shear fabrics postdated metamorphism.

Few prograde metamorphic minerals other than quartz, ilmenite and rutile are preserved as inclusions in garnet. However, sample BU08-47, just above the Main Central Thrust, does preserve staurolite inclusions in the outer margin of the garnet. Staurolite and kyanite are also present in the matrix, although kyanite is clearly deformed (Long and McQuarrie, 2010). Both BU08-47 and BU08-48 contain fibrolitic sillimanite that has preferentially nucleated along plagioclase grain boundaries (Fig. S2E). This texture has been documented elsewhere in rocks where sillimanite would not be stable as a matrix phase (Spear, 1982; Kohn et al., 1993), and is generally viewed as the product of post-peak metasomatism (e.g. see Vernon, 1979; Wintsch and Andrews, 1988). We do not know whether this explanation applies to all occurrences of fibrolitic sillimanite in samples BU08-47 and BU08-48, but we do not ascribe regional metamorphic significance to it. Similar textures have been documented in the central Nepal Himalaya (e.g., Kaneko, 1995; Corrie and Kohn, 2011).

Fig. S1 Corrie et al.



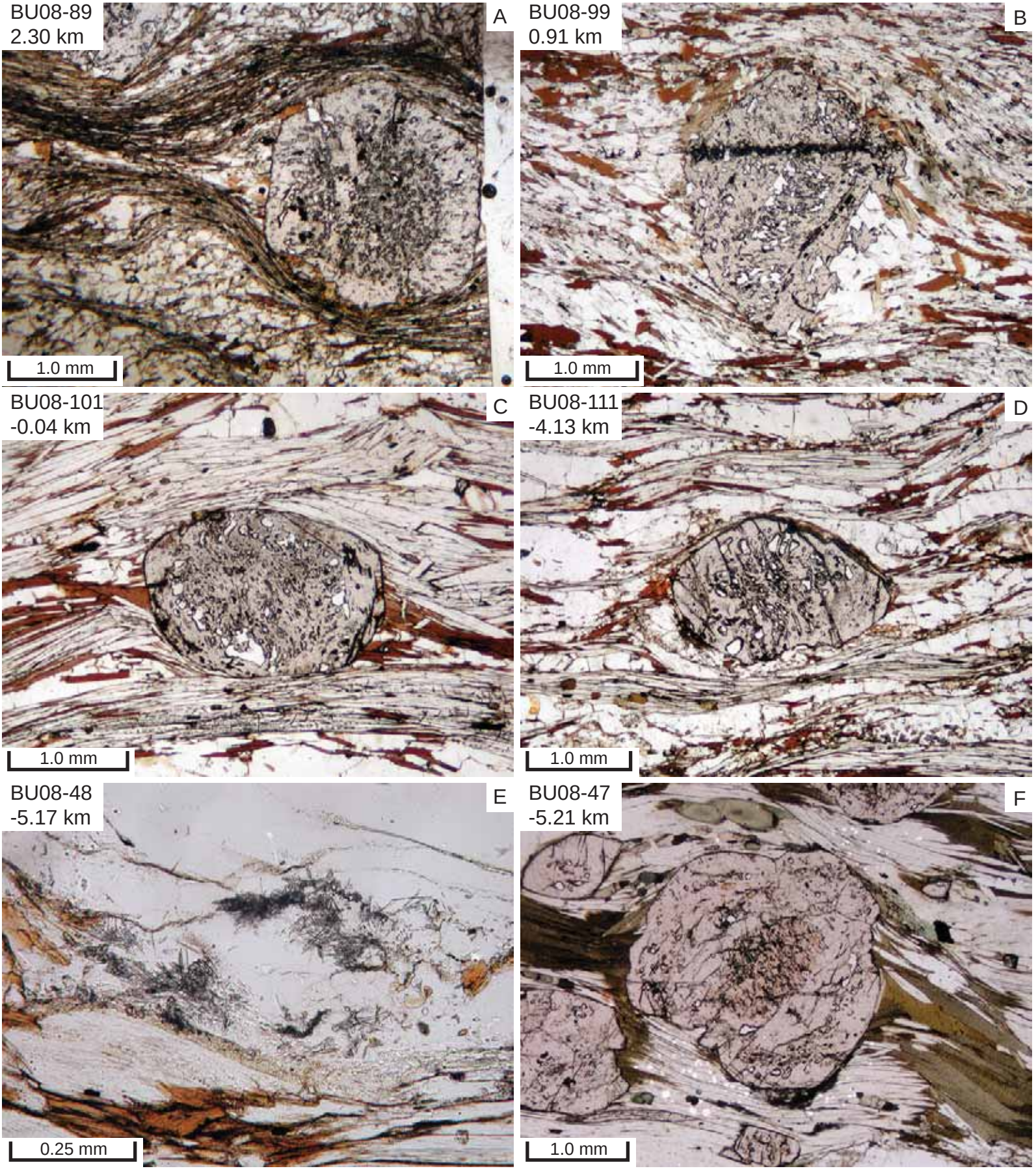

BU08-89
2.30 km
A
1.0 mm
BU08-99
0.91 km
B
1.0 mm
BU08-101
-0.04 km
C
1.0 mm
BU08-111
-4.13 km
D
1.0 mm
BU08-48
-5.17 km
E
0.25 mm
BU08-47
-5.21 km
F
1.0 mm

Table S1. Calculated temperatures and pressures from rocks of the Black Mountain region, central Bhutan

Sample	T (°C)	P (kbar)	Structural Distance (km)	UTM WGS84		
Maneting						
K11B023	505 ± 25	5.0 ± 1.0	4.09	46R	264138	3013732
BU08-95	475 ± 25	5.0 ± 1.0	4.05	46R	264979	3013729
K11B022	505 ± 15	5.5 ± 1.0	4.05	46R	263814	3014511
K11B026	525 ± 25	6.0 ± 1.5	3.62	46R	266333	3013858
K11B021	520 ± 15	6.0 ± 0.5	3.40	46R	263663	3014996
K11B032	475 ± 15	4.5 ± 1.0	3.14	46R	269635	3011113
BU08-90	560 ± 20	6.5 ± 1.5	2.58	46R	273219	3011207
BU08-89	575 ± 15	7.5 ± 1.0	2.30	46R	274560	3009883
Chekha						
K11B020	525 ± 20	7.0 ± 1.0	2.05	46R	263034	3016369
BU08-88	575 ± 20		2.04	46R	272778	3009420
K11B019	550 ± 15	7.5 ± 1.0	2.00	46R	265318	3019494
BU08-87	600 ± 25		1.62	46R	271659	3007932
BU08-99	590 ± 25	7.5 ± 1.0	0.91	46R	262944	3022568
K11B054	520 ± 15	7.5 ± 1.0	0.38	46R	268613	3003660
GH						
BU08-65	550 ± 20	6.5 ± 1.5	-0.03	46R	269650	3002688
BU08-101	615 ± 20	9.5 ± 1.0	-0.04	46R	261955	3025760
BU08-63	570 ± 15	7.5 ± 1.0	-0.08	46R	272431	3002729
BU08-66	540 ± 15	6.5 ± 0.5	-0.20	46R	269382	3001932
K11B052	565 ± 35		-0.41	46R	269116	3001496
BU08-53	620 ± 20	9.0 ± 1.0	-0.84	46R	274020	3001460
BU08-102	605 ± 20	9.0 ± 1.0	-0.87	46R	259982	3027408
BU08-54	640 ± 30		-1.23	46R	275668	3001839
BU08-104	580 ± 20	9.0 ± 0.5	-1.59	46R	254160	3031422
BU08-106	615 ± 15	9.0 ± 0.5	-2.47	46R	256213	3034572
BU08-109	675 ± 25	9.0 ± 1.0	-2.51	46R	250435	3038734
BU08-78	565 ± 20	7.5 ± 1.0	-2.72	46R	265420	2994136
BU08-58	665 ± 20	9.0 ± 1.0	-3.03	46R	278559	2998647
BU08-77	595 ± 25	7.5 ± 1.0	-3.54	46R	264613	2992743
BU08-59	670 ± 15	10.0 ± 0.5	-3.62	46R	279393	2997794
BU08-76	665 ± 25	10.0 ± 1.5	-3.98	46R	263380	2990275
BU08-75	675 ± 15	9.5 ± 0.5	-4.01	46R	259986	2989903
BU08-111	665 ± 15	9.5 ± 1.0	-4.13	46R	254080	3043077
BU08-74	725 ± 20	10.5 ± 1.0	-5.17	46R	257152	2986268
BU08-48	655 ± 15	11.0 ± 0.5	-5.17	46R	280649	2993831
BU08-47	660 ± 20	11.0 ± 1.0	-5.21	46R	280969	2993822

Variable	Slope	Std. err.	Intercept	Std. err.	R^2
P	-0.568	0.042	7.70	0.17	0.872
T	-19.7	1.7	581	5	0.811

Note: All temperatures and associated errors rounded to nearest 5°C, pressures and associated errors to 0.5 kbar.

Table S2. Representive mineral compositions used for P-T calculations of rocks from the GH in central Bhutan

Garnet

Sample	BU08-74	BU08-75	BU08-76	BU08-77	BU08-78	K11B052	BU08-66	BU08-65	BU08-47	BU08-48	BU08-59	BU08-58	BU08-54
Si	2.945	2.914	2.964	2.973	2.968	2.925	2.981	2.970	2.926	2.951	2.956	2.947	2.952
Ti	0.001	0.000	0.002	0.001	0.001	0.003	0.004	0.003	0.001	0.000	-	0.000	0.002
Al	2.032	2.052	2.022	2.018	2.035	2.050	2.077	2.021	2.040	2.041	2.045	2.016	2.023
Mg	0.416	0.332	0.279	0.252	0.191	0.051	0.207	0.194	0.624	0.548	0.544	0.214	0.304
Ca	0.188	0.164	0.266	0.179	0.270	0.174	0.309	0.293	0.272	0.239	0.098	0.317	0.080
Mn	0.114	0.165	0.156	0.224	0.093	0.022	0.315	0.071	0.091	0.033	0.167	0.577	0.014
Fe	2.338	2.432	2.333	2.368	2.452	2.822	2.081	2.457	2.094	2.215	2.211	1.970	2.659
Na	0.006	-	0.003	0.003	0.006	-	0.003	0.007	0.004	0.002	0.003	0.005	-
K	0.001	0.001	0.000	-	0.001	0.000	-	0.000	0.001	-	0.001	0.002	-
Wt% Total	100.147	99.661	100.342	100.968	100.077	100.612	99.747	100.297	99.079	100.689	100.057	100.740	100.500
Alm	0.765	0.786	0.769	0.783	0.816	0.920	0.715	0.815	0.680	0.730	0.732	0.640	0.870
Grs	0.062	0.053	0.088	0.059	0.090	0.057	0.106	0.097	0.088	0.079	0.033	0.103	0.026
Prp	0.136	0.107	0.092	0.083	0.063	0.017	0.071	0.064	0.203	0.180	0.180	0.070	0.099
Sps	0.037	0.053	0.051	0.074	0.031	0.007	0.108	0.024	0.029	0.011	0.055	0.187	0.005
Fe/(Fe+Mg)	0.849	0.880	0.893	0.904	0.928	0.982	0.910	0.927	0.770	0.802	0.803	0.902	0.897

Cations normalized to 12 oxygens.

Plagioclase

Sample	BU08-74	BU08-75	BU08-76	BU08-77	BU08-78	K11B052	BU08-66	BU08-65	BU08-47	BU08-48	BU08-59	BU08-58	BU08-54
XAn(%)	17.2	13.4	16.1	14.8	18.1		23.3	20.5	21.0	17.3	12.6	21.9	
Wt% Total	99.039	100.098	100.456	100.400	100.768		99.363	100.387	99.482	99.207	100.551	100.704	

Biotite

Sample	BU08-74	BU08-75	BU08-76	BU08-77	BU08-78	K11B052	BU08-66	BU08-65	BU08-47	BU08-48	BU08-59	BU08-58	BU08-54
Si	2.709	2.684	2.719	2.681	2.705	2.616	2.710	2.704	2.765	2.735	2.719	2.718	2.677
Ti	0.113	0.126	0.136	0.113	0.100	0.117	0.088	0.094	0.101	0.074	0.128	0.163	0.114
Al	1.669	1.728	1.708	1.698	1.768	1.829	1.746	1.760	1.590	1.653	1.697	1.607	1.774
Mg	1.056	0.932	0.902	0.927	0.830	0.263	1.014	0.874	1.492	1.377	1.253	0.836	0.890
Ca	0.000	-	-	-	-	-	0.000	0.001	-	0.001	0.001	0.000	0.001
Mn	0.006	0.006	0.005	0.008	0.003	0.001	0.004	0.001	0.007	0.001	0.005	0.024	0.000
Fe	1.336	1.397	1.415	1.477	1.492	2.078	1.314	1.474	0.939	1.059	1.087	1.489	1.450
Na	0.027	0.033	0.027	0.024	0.025	0.036	0.030	0.030	0.057	0.044	0.051	0.008	0.046
K	0.880	0.869	0.785	0.881	0.795	0.861	0.875	0.798	0.834	0.883	0.772	0.948	0.786
Wt% Total	94.115	94.370	94.860	94.849	94.436	95.164	94.629	94.192	94.512	94.024	94.026	94.383	94.235
Fe/(Fe+Mg)	0.559	0.600	0.611	0.614	0.643	0.888	0.565	0.628	0.386	0.435	0.465	0.640	0.620

Cations normalized on an anhydrous basis to 11 oxygens.

Muscovite

Sample	BU08-74	BU08-75	BU08-76	BU08-77	BU08-78	K11B052	BU08-66	BU08-65	BU08-47	BU08-48	BU08-59	BU08-58	BU08-54
Si		3.053	3.052	3.033	3.051		3.024	3.107				3.110	
Ti		0.040	0.028	0.026	0.015		0.014	0.013				0.039	
Al		2.783	2.823	2.833	2.824		2.871	2.759				2.636	
Mg		0.078	0.066	0.057	0.076		0.057	0.071				0.113	
Ca		-	-	-	-		-	-				-	
Mn		-	-	-	-		0.000	-				0.001	
Fe		0.073	0.067	0.070	0.089		0.061	0.072				0.136	
Na		0.169	0.169	0.158	0.128		0.174	0.152				0.051	
K		0.799	0.764	0.842	0.795		0.816	0.794				0.934	
Wt% Total		94.122	94.893	94.689	94.580		94.173	95.162				94.368	

Cations normalized on an anhydrous basis to 11 oxygens.

Table S2. Representive mineral compositions used for P-T calculations of rocks from the GH in central Bhutan (cont.)

Garnet

Sample	BU08-53	BU08-63	BU08-101	BU08-102	BU08-104	BU08-106	BU08-109	BU08-111
Si	2.955	2.950	2.945	2.955	2.956	2.966	2.937	2.950
Ti	0.002	0.000	0.002	0.001	0.007	0.000	0.001	-
Al	2.047	2.031	2.036	2.034	2.035	2.002	2.033	2.039
Mg	0.320	0.297	0.335	0.283	0.222	0.323	0.333	0.404
Ca	0.225	0.283	0.234	0.278	0.204	0.162	0.208	0.173
Mn	0.074	0.043	0.037	0.097	0.640	0.181	0.105	0.095
Fe	2.395	2.428	2.445	2.378	1.953	2.392	2.425	2.370
Na	0.003	0.004	-	-	0.003	0.007	0.000	-
K	0.001	0.000	-	0.000	0.001	0.000	0.002	0.000
Wt% Total	100.081	99.279	100.207	100.537	100.869	99.696	99.492	99.965
Alm	0.795	0.796	0.801	0.783	0.647	0.782	0.790	0.779
Grs	0.075	0.093	0.077	0.091	0.068	0.053	0.068	0.057
Prp	0.106	0.097	0.110	0.093	0.074	0.106	0.108	0.133
Sps	0.025	0.014	0.012	0.032	0.212	0.059	0.034	0.031
Fe/(Fe+Mg)	0.882	0.891	0.880	0.894	0.898	0.881	0.879	

Cations normalized to 12 oxygens.

Plagioclase

Sample	BU08-53	BU08-63	BU08-101	BU08-102	BU08-104	BU08-106	BU08-109	BU08-111
XAn(%)	16.6	23.4	15.0	18.0	9.5	17.7	18.6	19.1
Wt% Total	100.022	99.939	100.051	99.693	100.415	100.066	99.141	99.196

Biotite

Sample	BU08-53	BU08-63	BU08-101	BU08-102	BU08-104	BU08-106	BU08-109	BU08-111
Si	2.730	2.720	2.689	2.770	2.701	2.674	2.669	2.688
Ti	0.116	0.089	0.117	0.098	0.134	0.134	0.134	0.155
Al	1.712	1.743	1.736	1.727	1.690	1.725	1.721	1.712
Mg	1.007	1.080	1.060	0.944	0.973	1.006	0.935	1.054
Ca	0.000	-	0.000	0.010	0.002	-	0.001	-
Mn	0.003	0.003	0.001	0.005	0.017	0.006	0.008	0.006
Fe	1.299	1.254	1.289	1.271	1.340	1.328	1.372	1.258
Na	0.031	0.029	0.040	0.019	0.026	0.044	0.040	0.046
K	0.827	0.832	0.820	0.865	0.895	0.865	0.952	0.808
Wt% Total	94.531	94.647	94.644	94.283	95.517	94.249	94.682	94.646
Fe/(Fe+Mg)	0.563	0.537	0.549	0.574	0.579	0.569	0.595	0.544

Cations normalized on an anhydrous basis to 11 oxygens.

Muscovite

Sample	BU08-53	BU08-63	BU08-101	BU08-102	BU08-104	BU08-106	BU08-109	BU08-111
Si	3.034	3.096	3.067	3.060	3.125	3.043	3.041	3.055
Ti	0.016	0.015	0.022	0.028	0.018	0.023	0.027	0.060
Al	2.867	2.770	2.799	2.820	2.666	2.827	2.831	2.769
Mg	0.059	0.082	0.081	0.060	0.119	0.066	0.059	0.075
Ca	-	0.001	0.000	0.000	0.000	-	0.000	-
Mn	0.000	0.000	-	0.000	0.003	-	-	0.000
Fe	0.052	0.055	0.057	0.055	0.100	0.066	0.065	0.064
Na	0.207	0.141	0.233	0.177	0.101	0.157	0.167	0.160
K	0.756	0.823	0.726	0.775	0.873	0.824	0.812	0.785
Wt% Total	94.319	94.466	94.720	94.817	94.783	94.361	94.095	94.485

Cations normalized on an anhydrous basis to 11 oxygens.

Table S3. Representive mineral compositions used for P-T calculations of rocks from the Chekha Formation in central Bhutan

Garnet

Sample	K11B054	BU08-88	BU08-99	K11B019	K11B020
Si	2.933	2.953	2.937	3.015	2.979
Ti	0.002	0.005	0.001	0.004	0.013
Al	2.025	2.024	2.030	1.989	2.042
Mg	0.172	0.046	0.235	0.183	0.154
Ca	0.383	0.879	0.389	0.734	0.486
Mn	0.421	0.451	0.365	0.542	0.173
Fe	2.114	1.669	2.089	1.518	2.141
Na	-	0.003	-	-	-
K	0.001	0.003	0.002	-	-
Wt% Total	100.018	100.513	99.857	100.411	101.257
Alm	0.684	0.548	0.679	0.510	0.725
Grs	0.124	0.289	0.126	0.247	0.164
Prp	0.056	0.015	0.076	0.062	0.052
Sps	0.136	0.148	0.118	0.182	0.059
Fe/(Fe+Mg)	0.925	0.973	0.899	0.892	0.933

Cations normalized to 12 oxygens.

Plagioclase

Sample	K11B054	BU08-88	BU08-99	K11B019	K11B020
XAn(%)	16.3	27.7	27.7	35.1	27.5
Wt% Total	100.42	99.33	99.33	99.91	99.64

Biotite

Sample	K11B054	BU08-88	BU08-99	K11B019	K11B020
Si	2.738	2.717	2.723		2.733
Ti	0.104	0.207	0.128		0.106
Al	1.662	1.633	1.663		1.752
Mg	0.964	0.400	0.991		0.870
Ca	-	0.000	-		-
Mn	0.010	0.023	0.011		0.005
Fe	1.388	1.830	1.342		1.405
Na	0.020	0.015	0.022		0.011
K	0.899	0.885	0.900		0.818
Wt% Total	94.551	95.019	95.191		94.334
Fe/(Fe+Mg)	0.590	0.821	0.575		0.618

Cations normalized on an anhydrous basis to 11 oxygens.

Muscovite

Sample	K11B054	BU08-88	BU08-99	K11B019	K11B020
Si	3.075		3.080		3.135
Ti	0.016		0.029		0.014
Al	2.732		2.728		2.713
Mg	0.079		0.100		0.085
Ca	-		-		0.001
Mn	0.002		0.000		-
Fe	0.148		0.087		0.080
Na	0.130		0.089		0.077
K	0.844		0.899		0.858
Wt% Total	95.060		94.551		94.724

Cations normalized on an anhydrous basis to 11 oxygens.

Hornblende

Sample	K11B054	BU08-88	BU08-99	K11B019	K11B020
Si				6.283	
Ti				0.048	
Al				2.796	
Mg				1.896	
Ca				1.853	
Mn				0.053	
Fe				2.080	
Na				0.429	
K				0.098	
Wt% Total				97.039	
Fe/(Fe+Mg)				0.523	

Cations normalized on an anhydrous basis to 23 oxygens.

Table S4. Representive mineral compositions used for P-T calculations of rocks from the Manteting Formation in central Bhutan

Garnet

Sample	BU08-89	BU08-90	K11B032	K11B026	BU08-95	K11B023	K11B021	K11B022
Si	2.945	2.990	3.021	2.988	2.979	2.934	3.015	2.920
Ti	0.002	0.023	0.017	0.002	0.002	0.002	0.001	0.001
Al	2.047	1.983	1.959	2.017	2.028	2.025	2.007	2.030
Mg	0.251	0.289	0.127	0.189	0.143	0.151	0.150	0.162
Ca	0.260	0.226	0.696	0.401	0.198	0.211	0.337	0.326
Mn	0.005	0.039	0.828	0.152	0.308	0.236	0.234	0.190
Fe	2.517	2.418	1.337	2.252	2.344	2.491	2.238	2.435
Na	0.005	0.044	-	0.005	0.006	-	-	0.001
K	0.002	0.013	-	-	0.001	0.001	-	0.001
Wt% Total	100.111	101.989	100.981	100.681	100.252	99.984	100.590	100.004
Alm	0.830	0.814	0.447	0.752	0.783	0.807	0.756	0.782
Grs	0.086	0.076	0.233	0.134	0.066	0.068	0.114	0.105
Prp	0.083	0.097	0.042	0.063	0.048	0.049	0.051	0.052
Sps	0.002	0.013	0.277	0.051	0.103	0.076	0.079	0.061
Fe/(Fe+Mg)	0.909	0.893	0.913	0.923	0.942	0.943	0.937	0.938

Cations normalized to 12 oxygens.

Plagioclase

Sample	BU08-89	BU08-90	K11B032	K11B026	BU08-95	K11B023	K11B021	K11B022
XAn(%)	20.0	22.3	36.5	30.0	15.9	16.9	22.4	22.6
Wt% Total	100.44	100.04	99.20	100.48	100.26	100.15	99.22	100.78

Biotite

Sample	BU08-89	BU08-90	K11B032	K11B026	BU08-95	K11B023	K11B021	K11B022
Si	2.721	2.692	2.709	2.728	2.766	2.696	2.756	2.722
Ti	0.095	0.092	0.101	0.097	0.103	0.105	0.097	0.099
Al	1.729	1.786	1.656	1.689	1.778	1.751	1.703	1.742
Mg	0.943	0.917	1.168	0.979	0.773	0.791	0.845	0.865
Ca	0.000	0.014	-	-	0.005	0.000	-	0.002
Mn	0.004	0.012	0.021	0.004	0.006	0.005	0.005	0.003
Fe	1.402	1.400	1.231	1.393	1.377	1.585	1.487	1.466
Na	0.032	0.056	0.018	0.018	0.011	0.012	0.012	0.019
K	0.818	0.764	0.933	0.856	0.855	0.772	0.795	0.800
Wt% Total	94.455	95.706	94.758	94.037	94.463	94.645	94.353	94.813
Fe/(Fe+Mg)	0.598	0.604	0.513	0.623	0.641	0.667	0.638	0.629

Cations normalized on an anhydrous basis to 11 oxygens.

Muscovite

Sample	BU08-89	BU08-90	K11B032	K11B026	BU08-95	K11B023	K11B021	K11B022
Si	3.052	3.083	3.166	3.053	3.098	3.061	3.091	3.088
Ti	0.014	0.027	0.017	0.015	0.014	0.013	-	0.014
Al	2.855	2.755	2.577	2.832	0.008	2.820	2.782	2.783
Mg	0.049	0.093	0.159	0.062	2.745	0.059	0.078	0.074
Ca	-	0.010	0.001	0.000	0.001	0.000	-	0.000
Mn	-	0.008	0.004	0.001	0.077	-	-	0.000
Fe	0.061	0.064	0.121	0.078	0.145	0.090	0.113	0.081
Na	0.220	0.229	0.054	0.135	0.079	0.168	0.059	0.114
K	0.725	0.717	0.913	0.805	0.833	0.769	0.849	0.809
Wt% Total	94.811	95.803	94.038	95.174	94.407	94.710	94.837	96.444

Cations normalized on an anhydrous basis to 11 oxygens.

Chlorite

Sample	BU08-89	BU08-90	K11B032	K11B026	BU08-95	K11B023	K11B021	K11B022
Si	2.558		2.671		2.708		2.608	
Ti	0.006		0.006		0.007		0.006	
Al	2.926		2.730		3.075		2.930	
Mg	1.856		2.410		1.342		1.578	
Ca	0.001		0.001		0.001		0.003	
Mn	0.004		0.048		0.016		0.016	
Fe	2.622		2.091		2.534		2.776	
Na	-		0.000		0.022		0.001	
K	0.002		0.002		0.103		0.007	
Wt% Total	87.461		87.760		87.528		87.077	
Fe/(Fe+Mg)	0.585		0.465		0.654		0.637	

Cations normalized on an anhydrous basis to 14 oxygens.

Table S5. Mineral compositions used for P-T path calculations of rocks from central Bhutan

Sample	Xan core	Xalm core	Xsps core	Xgrs core	ΔT (°C)	ΔP (bars)	XMg,chl	XFe,chl	XMn,chl
BU08-63	0.37	0.472	0.26	0.246	-95	-2200	0.472	0.526	0.002
BU08-63 (mid)		0.703	0.041	0.197	-40	0			
BU08-89	0.275	0.582	0.194	0.201	-35	200			
BU08-95	0.22	0.665	0.211	0.089	-20	-800			
K11B054	0.25	0.553	0.284	0.125	-25	-2200	0.417	0.575	0.008
K11B021	0.28	0.594	0.216	0.161	-25	-600			
K11B032	0.45	0.436	0.338	0.188	-15	-1200			

Note 1: ΔT and ΔP rounded to nearest 5 °C and 100 bars
Note 2: chlorite compositions are assumed matrix compositions for rocks that lack prograde chlorite

Table S6. Zr-in-Rutile results.

Sample	SiO2 (wt%)	Al2O3 (wt%	CaO (wt%)	FeO (wt%)	TiO2 (wt%)	ZrO2 (wt%)	Total	Zr (ppm)	T (°C) at 7 kbar
BU08-87_1	0.094	0.072	0.019	0.321	95.62	0.013	96.14	98	556
BU08-87_2	0.159	0.101	0.057	0.378	96.06	0.020	96.78	150	585
BU08-87_3	0.084	0.066	0.012	0.519	95.73	0.028	96.44	210	609
BU08-87_6	0.109	0.059	-	0.169	96.63	0.025	96.99	187	601
BU08-87_7	0.065	0.061	0.002	0.164	96.91	0.023	97.23	170	594
BU08-87_8	0.091	0.079	0.016	0.229	96.48	0.029	96.92	212	610
BU08-87_9	0.087	0.062	0.012	0.199	96.76	0.037	97.16	272	629
								avg.	598
								st. dev.	23

Table S7. Mineral assemblages for rocks central Bhutan

Sample	Rock Unit	Rock Type	Pl	Bt	Grt	Ms	Chl	Ky/Sil	Rut	Mnz	Ilm	Tur	Other
BU08-45	GHS	Gneiss	X	X									aln
BU08-47	GHS	Schist	X	X	X	X		ky	X	X		X	st
BU08-48	GHS	Schist	X	X	X	X		ky		X		X	st
BU08-49a	Chekha	Quartzite	X	X		X	X					X	
BU08-50a	Chekha	Quartzite	X	X		X				X	X	X	
BU08-51a	Chekha	Quartzite		X		X						X	
BU08-52	GHS	Schist		X	X	X					X		
BU08-53a	GHS	Schist	X	X	X	X					X	X	
BU08-54	GHS	Gneiss		X	X	X						X	
BU08-55	GHS	Schist	X	X	X	X						X	
BU08-56	GHS	Gneiss	X	X		X							ksp
BU08-57	GHS	Gneiss	X	X		X							cz
BU08-58	GHS	Gneiss	X	X	X	X	X						
BU08-59	GHS	Gneiss	X	X	X	X		ky	X	X			st
BU08-60	GHS	Schist	X	X	X	X							
BU08-62	GHS	Schist	X	X	X	X						X	
BU08-63	GHS	Schist	X	X	X	X					X		
BU08-64a	Chekha	Quartzite	X	X			X					X	mt
BU08-65a	GHS	Phyllite	X	X	X	X				X		X	hem
BU08-66	GHS	Schist	X	X	X	X				X		X	hem
BU08-67a	Chekha	Quartzite	X	X								X	hem
BU08-74b	GHS	Schist	X	X	X	X						X	
BU08-75	GHS	Schist	X	X	X	X						X	
BU08-76	GHS	Gneiss	X	X	X	X						X	
BU08-77	GHS	Gneiss	X	X	X	X						X	
BU08-78	GHS	Gneiss	X	X	X	X	X				X		
BU08-79a	GHS	Quartzite		X	X	X						X	
BU08-80a	GHS	Quartzite		X		X						X	
BU08-81a	GHS	Schist		X		X	X						mt
BU08-82a	GHS	Quartzite	X	X		X	X					X	
BU08-83a	GHS	Quartzite	X	X		X	X					X	aln
BU08-84a	GHS	Quartzite		X		X			X			X	
BU08-85a	GHS	Schist		X		X	X					X	
BU08-86a	Chekha	Quartzite		X					X				
BU08-87a	Chekha	Quartzite		X					X			X	
BU08-88a	Chekha	Quartzite		X	X	X							ksp
BU08-89	Chekha	Phyllite	X	X	X	X	X				X		
BU08-90a	Maneting	Phyllite	X	X	X	X	X				X	X	
BU08-91a	Chekha	Quartzite	X	X					X			X	
BU08-93a	Maneting	Phyllite		X		X	X					X	
BU08-94a	Maneting	Phyllite		X		X	X						
BU08-95a	Maneting	Phyllite	X	X	X	X	X				X		
BU08-96a	Maneting	Phyllite		X	X	X	X				X	X	
BU08-97a	Chekha	Quartzite		X	X							X	
BU08-98a	Chekha	Quartzite		X		X	X					X	
BU08-99a	Chekha	Quartzite	X	X	X	X					X	X	
BU08-100a	Chekha	Quartzite		X		X						X	
BU08-101a	GHS	Schist	X	X	X	X						X	
BU08-102a	GHS	Schist	X	X	X	X							
BU08-103	GHS	Schist		X		X						X	aln
BU08-104a	GHS	Quartzite	X	X	X	X						X	
BU08-105a	GHS	Quartzite		X								X	
BU08-106a	GHS	Schist	X	X	X	X				X			
BU08-107a	GHS	Quartzite		X		X							
BU08-109a	GHS	Schist	X	X	X	X					X	X	
BU08-110a	GHS	Schist		X	X	X						X	
BU08-111a	GHS	Gneiss	X	X	X	X		ky	X			X	
K11B019c	Chekha	Calc-silicate	X		X								cal, hbl, ttn
K11B020	Chekha	Phyllite	X	X	X	X						X	
K11B021	Maneting	Phyllite	X	X	X	X	X					X	
K11B022b	Maneting	Phyllite	X	X	X	X						X	
K11B023	Maneting	Phyllite	X	X	X	X							
K11B026	Maneting	Phyllite	X	X	X	X							
K11B032	Maneting	Phyllite	X	X	X	X	X					X	
K11B052b2	GHS	Schist		X	X							X	
K11B054b	Chekha	Phyllite	X	X	X	X							

Note: all samples contain quartz and apatite