GS-10 Regional granulite-facies metamorphism in the northeastern Kisseynew Domain, Manitoba (parts of NTS 63O)

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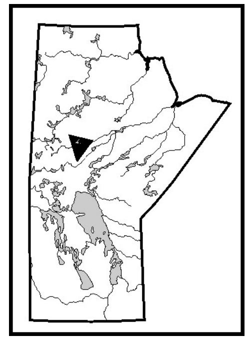

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Summary

Observed metamorphic assemblages in the Wuskwatim Lake corridor of the northeastern Kisseynew Domain indicate upper-amphibolite- and granulite-facies conditions in Burntwood migmatite, as well as in a structurally underlying basement-cover sequence thought to be correlative with the Superior Province and Ospwagan Group in the Thompson Nickel Belt. The high-temperature metamorphism occurred at about 775°C, 6.8 kbar and 1806 to 1797 Ma.

Introduction

The Superior Boundary Zone, separating the Superior Province from the Kisseynew Domain in northern Manitoba (Figure GS-10-1), has been the focus of much recent research (Zwanzig, 1997a, b, 1999; Macek and McGregor, 1998; Macek et al., 1999, 2000; Machado et al., 1999; White et al., 2002; Zwanzig and Böhm, 2002; Zwanzig et al., 2003; Percival et al., 2004, 2005; Hulbert et al., 2005; Rayner et al., GS-11, this volume). The Kisseynew Domain to the west (Figure GS-10-1) contains structural and mineralogical evidence for a protracted tectonic and metamorphic history during the Paleoproterozoic, including terminal collision with the Superior margin around 1.83 Ga. Companion reports (Zwanzig et al., GS-9, this volume; Percival et al., GS-8, this volume) outline evidence for rocks of Superior margin affinity (i.e., the Ospwagan Group and its Archean basement) in the eastern 60 km of the Kisseynew Domain, and this report presents evidence for the upper-amphibolite- to granulite-facies metamorphism of the Burntwood and Ospwagan groups.

Tectonostratigraphic framework

Fieldwork was carried out from fly camps on Wuskwatim, Threepoint, and Tullibee lakes, as well as on selected sections of the Burntwood River (Figure GS-10-1). Mapping was mainly restricted to shoreline exposures with a few short traverses to critical field areas. The main tectonostratigraphic units in the field area are orthogneiss of probable Superior Province affinity, Ospwagan Group-like metasedimentary rocks and paragneiss of the Burntwood Group.

Rocks of probable Superior Province affinity, observed in several parts of the map area, include high-grade plutonic, migmatitic and metamorphic rocks (Percival et al., 2005). Crosscutting dikes and veins form trains of boudins that are highly attenuated and locally folded. Outcrops of orthogneiss are universally characterized by assemblages and textures indicative of high peak metamorphic temperatures and variable amounts of strain.

Rocks of the Ospwagan Group unconformably overlie Archean basement gneiss within the Thompson Nickel Belt (Zwanzig, 1997a, b; Macek et al., 1999, 2000; Zwanzig and Böhm, 2002). The age of deposition of the Ospwagan Group in the Superior Province margin was constrained to be less than 1.974 Ga, based on the youngest detrital zircon of Hamilton and Bleeker (2002), and greater than ca. 1.883 Ga, based on the age of mafic intrusions of Hulbert et al. (2005). The Ospwagan Group stratigraphy is interpreted as a succession of continental shelf sediments with overlying rift-related volcanic rocks (Zwanzig, 1997a, b; Macek et al., 1999, 2000; Zwanzig and Böhm, 2002) that experienced subsequent high-temperature, low-pressure metamorphism. The Ospwagan Group includes the basal quartzitic Manasan Formation and the calcareous Thompson Formation, above which are the siliciclastic Pipe and Setting formations. The overlying Bah Lake assemblage consists of rift-related mafic volcanic rocks (*see* Zwanzig et al., Figure GS-9-2 this volume).

In the Wuskwatim Lake area, dark purple-grey, quartz-rich, garnetiferous paragneiss with 5 to 10% leucosome was considered as possibly correlative with the Manasan Formation of the Ospwagan Group. These rocks are cut by tourmaline-bearing pegmatitic granite and aplite. Iron formation and associated biotite±garnet–bearing paragneiss were considered possibly correlative with the Pipe Formation (Figure GS-10-2; *see also* Zwanzig et al., GS-9, this volume).

The Burntwood Group of the central Kisseynew Domain is composed of migmatitic turbidites deposited around 1.85 Ga. Two detrital zircon age modes are evident: abundant 1.84 to 1.89 Ga zircons and sparse Archean grains (Machado et al., 1999; Percival et al.,

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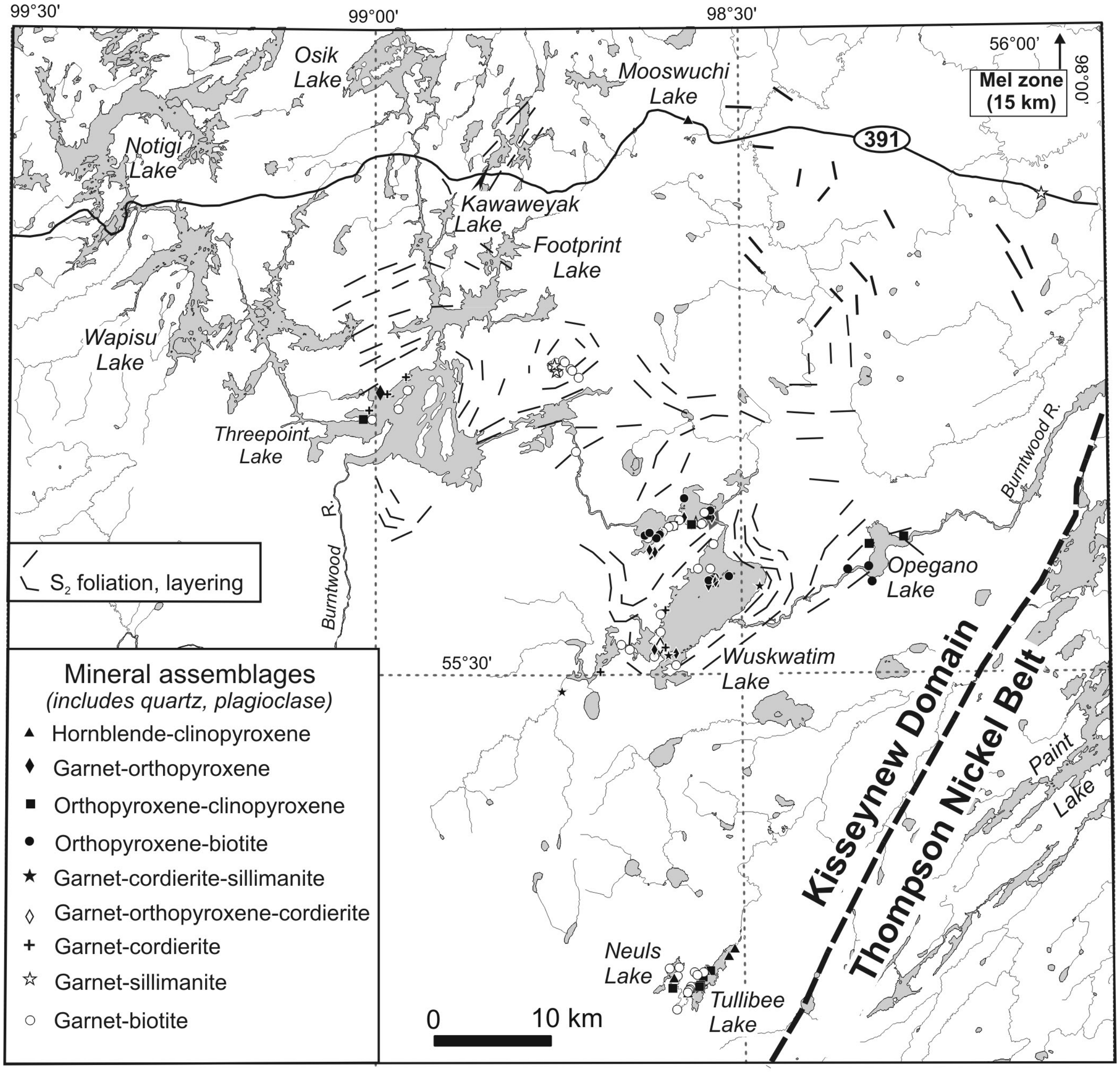

Figure GS-10-1: *Generalized map of the northeastern Kisseynew Domain, showing the locations of features referred to in the text and observed metamorphic assemblages.*

2005). The Burntwood Group is overlain by and laterally equivalent to coarse clastic rocks of the Missi Group, which are considered to be the terrestrial extension of the turbiditic facies. The Burntwood Group is characterized in the field area by migmatitic biotite-garnet gneiss (up to 75% leucosome) with common sillimanite, cordierite and graphite (Gordon, 1989), as well as newly reported orthopyroxene (Figure GS-10-3). Rare pods of calcareous material have haloes of biotite paragneiss.

Structural geometry

The structural geometry of the field area is outlined by Percival et al. (GS-8, this volume). Four deformation fabrics have been recognized within the three tectonostratigraphic units. The D_1 deformation involved east-verging F_1 folds (Zwanzig, 1999; Zwanzig and Böhm, 2002) and the thrusting of the Burntwood Group onto the Ospwagan Group. Thrust imbrication is inferred from the sharp truncation of the Ospwagan Group by the Burntwood Group above the Pipe Formation (Zwanzig and Böhm, 2002), accompanied by an abrupt change in Nd model ages across this boundary. The main metamorphic fabrics, S_2, were produced during D_2 and D_3 deformation according to previous regional-scale studies (Zwanzig, 1990, 1997a, b, 1999; Kraus and Menard, 1997; Menard and Gordon, 1997; Zwanzig and Böhm, 2002). In the present area, these regional D_2 and D_3 events cannot be resolved and may represent a single, progressive D_2 event. The D_3 deformation resulted in the folding of S_2 into upright open

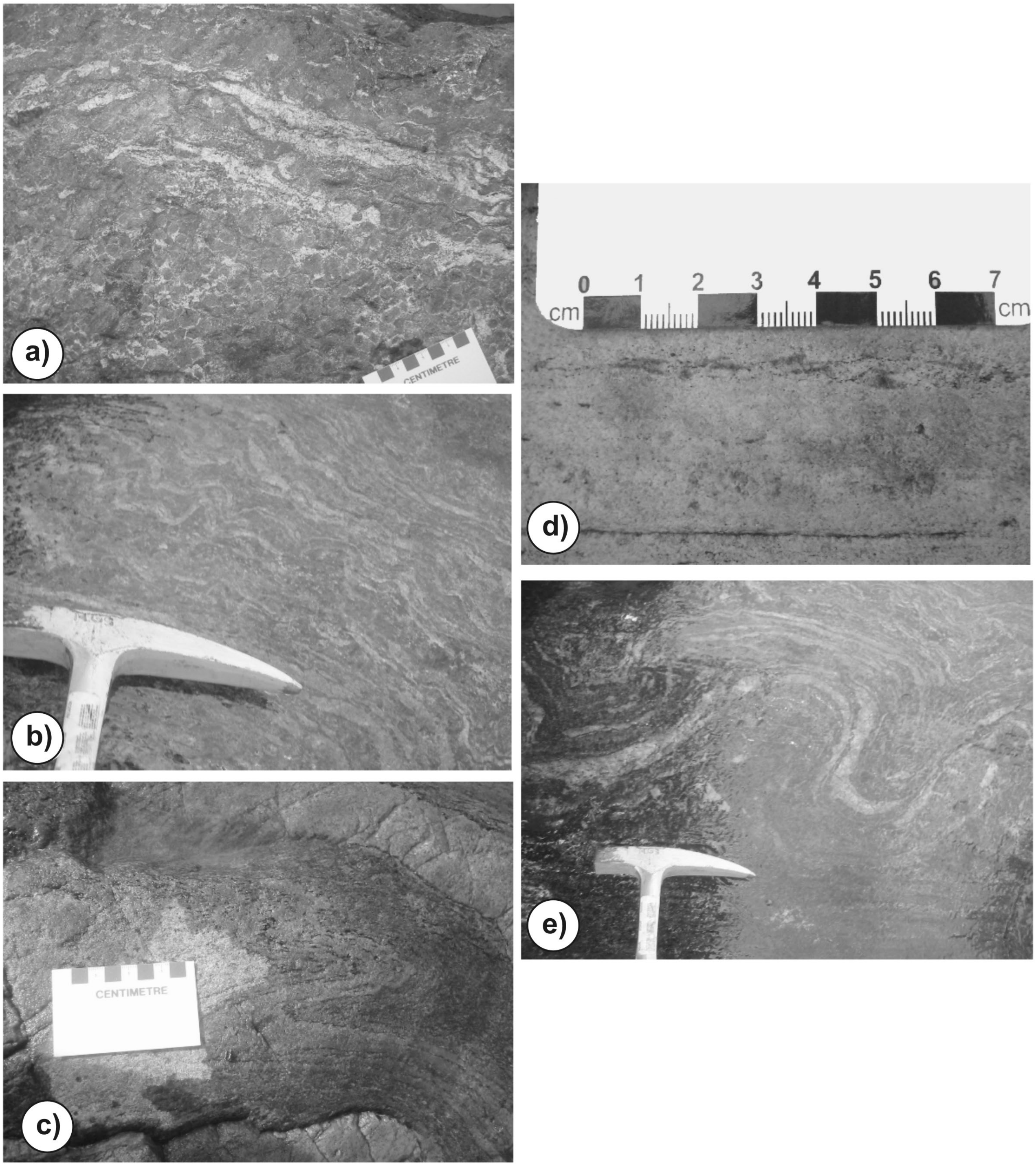

Figure GS-10-2: *Characteristic textures and assemblages in Ospwagan-like rocks:* ***a)****,* ***b)*** *and* ***c)*** *show sulphide- and silicate-facies iron formation containing garnet with plagioclase reaction rims and various amplitudes of folding;* ***d)*** *and* ***e)*** *show quartz-rich units with small garnets and common folds.*

northeast-trending F_3 folds that characterize much of the field area (Zwanzig and Böhm, 2002, Figure GS-14-5). The D_3 folds are locally modified by northwest-trending F_4 crossfolds, attributed to D_4 deformation. The late cross-folds are apparent in the field as plunge reversals of F_3 fold hinges.

Structural-metamorphic relationships

Structural-metamorphic relationships within the Kisseynew Domain and the western boundary zone of the Superior Province are complex. In the eastern Kisseynew Domain, four deformation events created up to three regional foliations and five generations of folds. An early

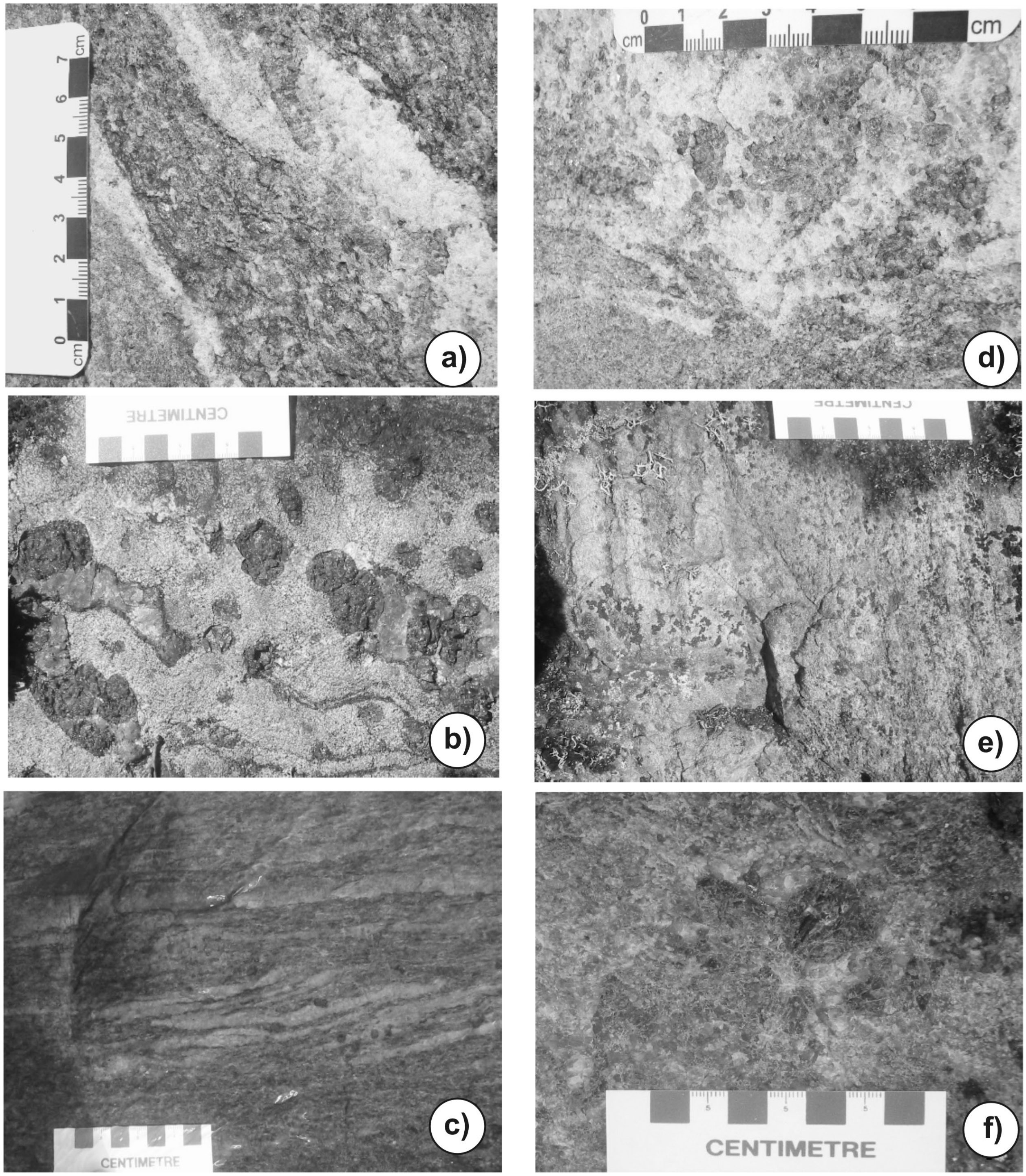

Figure GS-10-3: *Characteristic assemblages and textures of the Burntwood Group:* ***a)*** *large garnet porphyroblasts in layers surrounded by finer quartz and biotite separated by layers of quartz, K-feldspar and cordierite;* ***b)*** *biotite schlieren surround the garnet porphyroblasts;* ***c)*** *truncated layering in migmatitic Burntwood paragneiss;* ***d)*** *biotite-garnet-quartz-plagioclase-cordierite assemblage with about 10% leucosome;* ***e)*** *the sub-granulite grade Burntwood Group has preserved sedimentary layering;* ***f)*** *large cordierite grain in leucosome in paragneiss.*

S_1 chlorite foliation formed in the Snow Lake area due to the compaction and diagenesis synchronous with, and axial planar to, F_1 folds (Menard and Gordon, 1997), although this early foliation has not been recognized in more highly metamorphosed rocks (Machado et al., 1999; Zwanzig 1999). A composite S_2-S_3 progressive foliation developed during the main metamorphism, obliterating most evidence of the earlier deformation. Garnet growth began at temperatures around 500°C and occurred prior to, during, and after the development of D_2 structures, as inferred from microtextural relationships of inclusion trails in garnets (Kraus and Menard, 1997; Menard and Gordon, 1997). A moderately annealed biotite S_2 foliation indicates that temperatures rose after the development of this foliation (Zwanzig, 1999) and likely peaked during the D_2 deformation. Gneissosity attributed to S_2 and S_3 foliations is characterized by migmatitic layering and the alignment of peak metamorphic minerals. Local mutually overprinting S_2-S_3 and F_2-F_3 relationships indicate the synchronous development of these structures. The S_2-S_3 fabrics contain kinematic indicators suggestive of extensive layer parallel flow and attenuation during D_2. Foliations attributed to S_4, defined by retrograde assemblages of muscovite-chlorite or muscovite-sillimanite, overprint S_2-S_3 fabrics. In the Wuskwatim Lake area, local S_4 is developed parallel to the axial planes of northeast-striking F_4 folds. Thus, S_4 developed after the metamorphic peak. The presence of sillimanite in some of these assemblages suggests sustained high temperatures and moderate pressures following the metamorphic peak. Northwest-trending F_4 folds, inferred from plunge reversals of F_3 axes have no observed associated fabrics. The F_4 folds are interpreted to have folded the regional metamorphic isograds, bringing granulite-facies rocks to the surface in antiformal culminations.

Metamorphism

Regional metamorphism of the northeastern Kisseynew Domain is characterized by garnet- and cordierite-bearing migmatite indicative of low-pressure, high-temperature and upper-amphibolite-facies conditions (Baldwin et al., 1979; Gordon, 1989; White, 2005). Orthopyroxene occurrences in the Wuskwatim Lake area indicate local granulite-facies conditions.

Basement mineral assemblages

Metaplutonic rocks include poorly foliated grey to pink orthogneiss with some charnockite, highly foliated tonalite containing dark green-brown orthopyroxene and inclusions of enderbite and pyroxene-bearing tonalitic orthogneiss (Figure GS-10-4). Cream-coloured leucosome with <1 cm subhedral to euhedral orthopyroxene

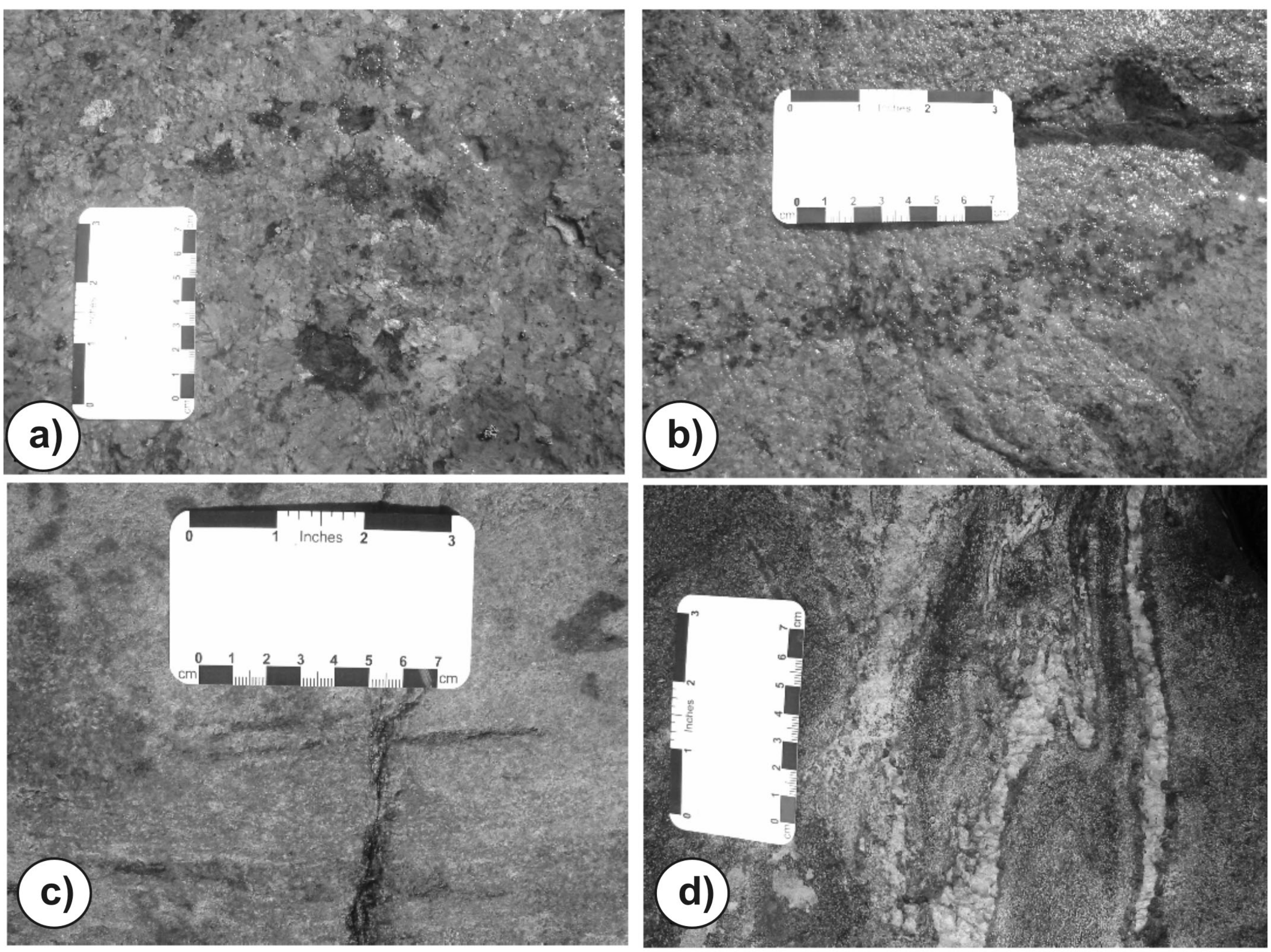

Figure GS-10-4: *Textures common in probable Archean basement in the Kisseynew Domain:* ***a)*** *small orthopyroxene and K-feldspar crystals in leucosome in charnockite;* ***b)*** *well-foliated tonalite with about 5 to 10% leucosome and melanosome rims;* ***c)*** *well-foliated pink gneiss with inclusions of tonalite;* ***d)*** *well-foliated tonalite with about 5 to 10% leucosome and melanosome rims.*

grains in a coarse-grained matrix of quartz, plagioclase and K-feldspar, constitute about 5 to 25% of these rocks. Gneissic foliation is locally tightly folded and may contain a strong rodding lineation of variable plunge. The orthogneiss is characterized by pyroxene-bearing assemblages composed of bronzy-coloured orthopyroxene, dark emerald green clinopyroxene and black hornblende in a matrix of plagioclase and quartz. Sparse paragneiss enclaves have garnet-orthopyroxene-hornblende-biotite assemblages and metabasite consists of an orthopyroxene-clinopyroxene-hornblende-plagioclase assemblage. The ubiquitous orthopyroxene in the basement assemblages indicates widespread granulite facies possibly Archean or Paleoproterozoic. More refined pressure-temperature-time estimates will be determined through electron microprobe analyses of coexisting minerals and geochronology.

Mineral assemblages in Ospwagan-like rocks

These rocks are the most mineralogically diverse group in the field. Assemblages are mainly characterized by biotite-garnet in quartzite and sulphide-bearing assemblages in iron formation. Leucosome within quartz-rich units are rich in quartz and contain orthopyroxene crystals up to 2 cm long. Local biotite-garnet-cordierite-orthopyroxene-melt assemblages indicate moderate pressures and temperatures in excess of ~750°C. This unit also contains aquamarine cordierite in association with fibrolitic sillimanite. Some retrograde replacement of cordierite by fine-grained chlorite is evident and may have been accomplished by the following hydration reaction:

Mg-cordierite + H_2O = Mg-chlorite + Al_2SiO_5 (Spear, 1995).

In the present area, the dominant aluminosilicate is coarse acicular sillimanite.

Burntwood assemblages and quantitative pressure-temperature conditions

Mineral assemblages of Burntwood paragneiss include quartz, plagioclase, biotite, garnet, sillimanite and cordierite. On a regional scale, staurolite is present at a lower metamorphic grade. Biotite and garnet are highly concentrated in the melanosome of migmatite, with minor quartz and plagioclase. Leucosome consists mostly of quartz and plagioclase and may have garnet at the margins. Small quantities of orthopyroxene are present in some localities. Its appearance may be represented by the low-pressure reaction:

biotite + plagioclase + quartz = orthopyroxene + K-feldspar + melt (Spear, 1995).

This reaction occurs at ~750 to 800°C within the sillimanite zone. The presence of cordierite in the leucosome may be represented by the reaction:

biotite + sillimanite = garnet + cordierite + melt (Spear, 1995)

and is indicative of temperatures of ~725 to 775°C (Gordon, 1989; White and Powell, 2002). These assemblages correspond to upper-amphibolite- and granulite-facies conditions, the field of which can be represented on a P-T diagram and correspond to temperatures in excess of 775°C (Figure GS-10-5).

A quantitative estimate of P-T conditions was determined for a garnet-cordierite-sillimanite-biotite-plagioclase-quartz diatexite from northeastern Wuskwatim Lake (Zwanzig et al., Figure GS-9-1, this volume). Mineral compositions were determined at the Geological Survey of Canada, Ottawa, on a Cameca Instruments SX50 electron microprobe operated in wavelength dispersive mode (Table GS-10-1). Structural formulae for core and rim compositions of weakly zoned garnet, cordierite, biotite and plagioclase grains were calculated using routine reduction procedures. Pressure-temperature conditions for core compositions were estimated from the intersection of equilibria defined by TWQ software (Berman, 1991, updated to version 2.02):

Mg-Fe cordierite = aluminosilicate + Mg-Fe garnet + quartz

anorthite = grossular + aluminosilicate + quartz

In addition, iron-magnesium exchange equilibria were calculated for garnet-cordierite and garnet-biotite pairs. The curves intersect at 6.8 kbar and 725 to 775°C (Figure GS-10-5), defining upper-amphibolite-facies conditions near the first appearance of orthopyroxene.

Metamorphic grade is slightly lower throughout most of the region (cf. Gordon, 1989), where the Burntwood paragneiss contains quartz, plagioclase, biotite, garnet and cordierite, with migmatitic leucosome and rare sillimanite. Diatexite with similar assemblages is common. Still lower-grade rocks occur locally, with relict sedimentary bedding (S_0). The primary textures are apparent in a patch north of the Burntwood River and east of Threepoint Lake (Figure GS-10-1), where assemblages are mainly garnet-biotite with some sillimanite. Retrograde reactions were only observed in the outcrop-scale mineral assemblages at one outcrop in western Threepoint Lake. There, coarse-grained platy muscovite occurs in association with sillimanite. This may indicate the coexistence of muscovite and melt, or more likely, the retrograde rehydration reaction:

sillimanite + K-feldspar + H_2O_{vapour} = muscovite + plagioclase + quartz (Spear, 1995).

Age of metamorphism

The age of peak metamorphism in the Kisseynew Domain has been most thoroughly researched by Parent et al. (1999) and Machado et al. (1999). The U-Pb ages below were determined on zircon and monazite that grew during

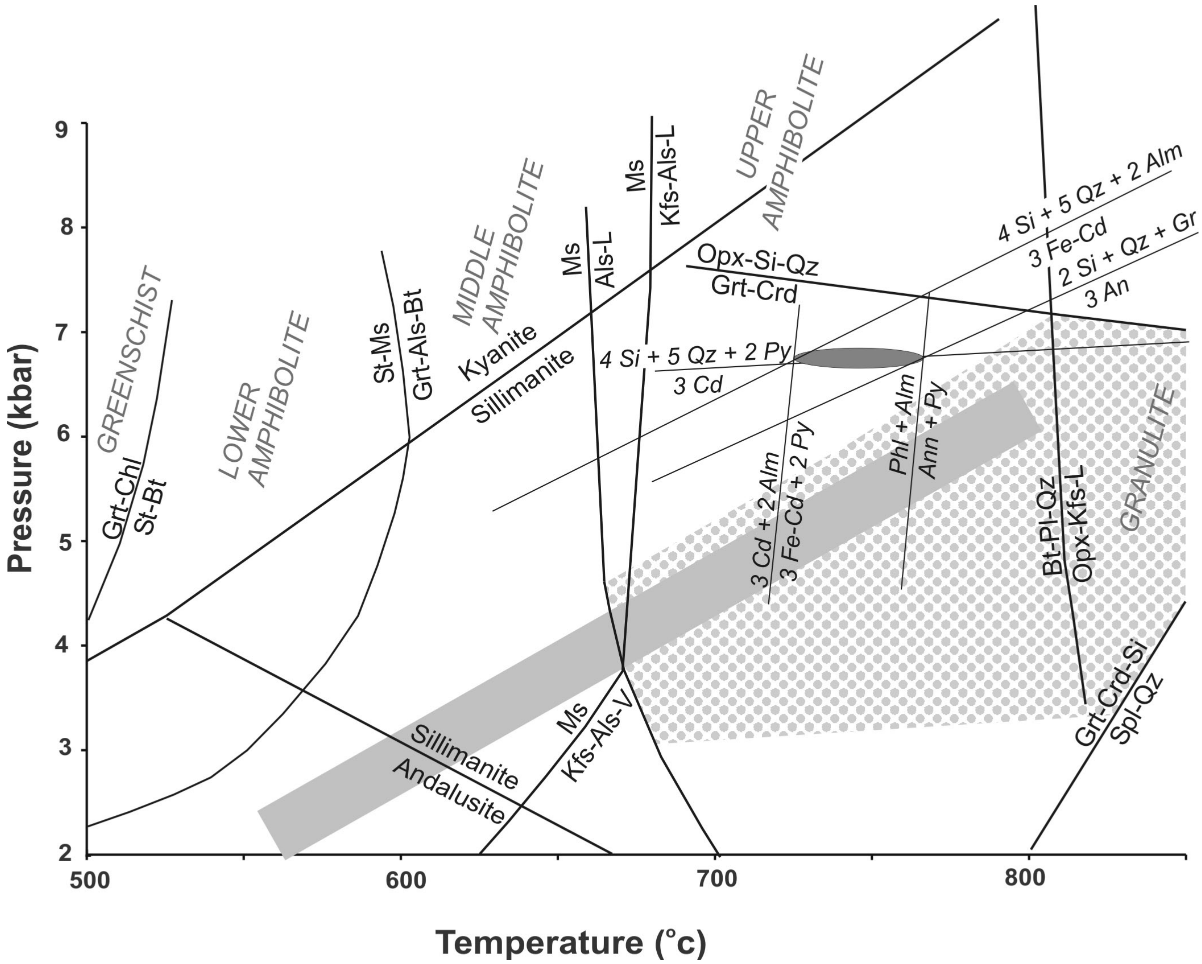

Figure GS-10-5: Summary of metamorphic conditions and possible metamorphic equilibria in the Kisseynew Domain (pressure-temperature [P-T] grid modified after *Percival and Skulski, 2000). The P-T estimate from this study is outlined in the medium grey oval (abbreviations: Alm, almandine; Als, aluminosilicate; An, anorthite; Ann, annite; Bt, biotite; Cd, cordierite; Chl, chlorite; Gr, grossular; Fe-Cd, iron cordierite; Kfs, K-feldspar; L, liquid; Ms, muscovite; Opx, orthopyroxene; Phl, phlogopite; Pl, plagioclase; Py, pyrope; Qz, quartz; Si, sillimanite; Spl, spinel; St, staurolite; V, vapour). The range of P-T estimates from central Kisseynew migmatite (pale grey band) is from Gordon (1989). The field of garnet-cordierite-sillimanite-melt for a metapelite with bulk FeO/MgO=1.845 from White and Powell (2002) is indicated by the stippled field. The stability field of this widespread assemblage in the central Kisseynew Domain is sensitive to pressure, temperature and bulk composition.*

Table GS-10-1: Electron microprobe data for garnet-cordierite-biotite-sillimanite-plagioclase-quartz paragneiss PBA04-08 (abbreviations: Gt, garnet; Cd, cordierite; Bt, biotite; Pl, plagioclase).

	Gt	Cd	Bt	Plg
SiO_2	37.5	47.5	35.4	62.2
TiO_2	0.1	0	5.9	0
Al_2O_3	21.2	32.5	15.5	23.4
Cr_2O_3	0	0	0.3	0
FeO	31.01	5.7	14.5	0
MnO	0.4	0	0.1	0
MgO	7.7	9.7	12.1	0
CaO	0.9	0	0	5.1
Na_2O	0	0.3	0.1	8.3
K_2O	0	0	9.3	0.5
Total	98.81	95.7	93.2	99.5

the metamorphism of the Kisseynew Domain (Machado et al., 1999; Parent et al., 1999). The oldest leucosome that records peak metamorphism contains sillimanite and is associated with F_2 folds and S_2 fabrics. Five euhedral monazites from a leucosome vein gave U-Pb ages of 1809 to 1803 Ma. Euhedral zircons within a diatexite folded by F_3 folds have an age of 1798+3/–2 Ma and constrain the minimum age of F_2 folding. The youngest pegmatite that cuts F_2 and F_3 folds, and was intruded just after deformation D_2, gives zircon U-Pb crystallization ages between 1818 and1788 Ma. The youngest of these dates was taken as the age of the pegmatite (Machado et al., 1999; Parent et al., 1999). Peak metamorphism and deformation within the Kisseynew Domain was interpreted to be continuous over the 30 Ma period of 1818 to 1785 Ma (Parent et al., 1999). Machado et al. (1999) suggested that high-grade metamorphic conditions persisted in the Kisseynew Domain until at least 1775 Ma. Somewhat younger peak metamorphism is indicated for the Superior Boundary Zone and Thompson Nickel Belt. Metamorphic zircon and monazite from the Thompson area yield U-Pb ages around 1770 Ma (Rayner et al., GS-11, this volume) and pegmatite has comparable crystallization ages (Machado et al., 1999).

This paper reports new monazite crystallization ages from a rock in the Wuskwatim Lake area to provide additional constraints on the timing of peak metamorphism. The sample is a felsic sedimentary unit initially described by Percival et al. (2005) and associated with the Ospwagan group sediments based on a small detrital zircon dataset (Geological Survey of Canada [GSC] lab number 8334). Additional detrital results for this sample are given in Zwanzig et al. (GS-9, this volume) and indicate a solely Archean source for the sediment, broadly consistent with Ospwagan-like Superior margin sedimentation.

Monazite ages determined by isotope dilution thermal ionization mass spectrometry (ID-TIMS) at the Geochronology Laboratory, Geological Survey of Canada, follow the sample dissolution and chemical methods as described in Parrish et al. (1987) and Davis et al. (1998). Individual grains were spiked with a mixed ^{205}Pb-^{233}U-^{235}U tracer solution calibrated to ±0.1% against a gravimetric solution and dissolved in high-pressure bombs in 6 N HCl. Data reduction and error propagation follow methods outlined in Roddick (1987). Uranium and lead isotopic ratios were measured using a Thermo Triton™ mass spectrometer operated in static multicollection mode. The ^{205}Pb, ^{206}Pb, ^{207}Pb and ^{208}Pb isotopes were measured simultaneously in Faraday collectors, with ^{204}Pb in an axial ion-counting secondary electron-multiplier. A Pb mass fractionation correction of 0.10 ±0.04%/amu was applied as determined by replicate analyses of the NBS981 standard (Table GS-10-2). Uranium fractionation was corrected using the ^{233}U-^{235}U double spike and was typically in the range of 0.12%/amu. Corrections for common Pb were made using Stacey-Kramers (1975) compositions. Concordia diagrams were generated using Isoplot™, version 3.00 (Ludwig, 2003). All ages and ellipses are given at the 2σ error level. The results are presented in Table GS-10-2 and plotted on Figure GS-10-6.

Seven monazite grains covering a range of size, colour, quality and morphology were selected for single-grain analysis. The ^{207}Pb-^{206}Pb ages range from 1797 to 1806 Ma but are consistently reversely discordant by 0.3 to 0.5%, with the exception of one concordant result. The reverse discordance is likely an analytical artifact, perhaps related to the dissolution of the monazites. The reverse discordance suggests that the U-Pb ages are inaccurate and therefore only the Pb-Pb ages will be considered further. The ^{207}Pb-^{206}Pb ages do not form a single statistical population, suggesting some geological scatter. This is consistent with prolonged metamorphism as proposed by previous workers (Gordon, 1989; Machado et al., 1999; Parent et al., 1999), although we cannot determine whether this was the result of two or more punctuated episodes or continuous growth over at least the 1806 to 1797 Ma interval. Backscattered electron imaging of the internal structure of the monazites along with in situ analysis would be needed to constrain this.

Summary and discussion

Deformation and high-grade metamorphism in the Kisseynew Domain occurred over a period of ~30 Ma (1818–1785 Ma) and created the dominant regional gneissosity and migmatitic layering. Deformation in the Kisseynew Domain is the product of collisions between volcanic arcs of the Trans-Hudson Orogen and subsequent collision with the Superior Province (Zwanzig, 1990; Ansdell, 2006). The D_1 deformation occurred pre-peak metamorphism and resulted in thrusting of the Burntwood Group onto the Ospwagan Group along a basal thrust fault (Zwanzig and Böhm, 2002). It is unclear whether S_1 in the Snow Lake Belt to the southwest is related (Menard and Gordon, 1997; Machado et al., 1999; Zwanzig, 1999). Regionally, D_2 deformation and peak metamorphism, indicated by metamorphic assemblages present in S_2-S_3 fabrics and foliation-parallel leucosome, occurred at temperatures of 750 to 800°C and pressures less than 5 kbar (Gordon, 1989; Zwanzig, 1990; Menard and Gordon 1997; White, 2005). In the Wuskwatim Lake region, post-peak metamorphic upright F_3 folds overprint the S_2-S_3 composite fabric. Together with younger crossfolds, these structures produce regional structural culminations that expose the basement-cover sequence and granulite-facies metamorphic rocks that equilibrated at pressures approximately 2 kbar higher (equivalent to 6 km depth) than the regional erosion level.

The single temperature estimate available for the Wuskwatim Lake area (Figure GS-10-1 and -5) falls within the range of regional peak metamorphic temperatures

Table GS-10-2: U-Pb analytical data for monazite, lab number Z8334.

						Isotopic Ratios[4]								Ages (Ma)[6]						
Fract.	Wt. ug	U ppm	Pb[1] ppm	$^{206}Pb/^{204}Pb$ [2]	Pb[3] pg	$^{208}Pb/^{206}Pb$	$^{207}Pb/^{235}U$	±1SE Abs	$^{206}Pb/^{238}U$	±1SE Abs	Corr.[5] coeff.	$^{207}Pb/^{206}Pb$	±1SE Abs	$^{206}Pb/^{238}U$	±2SE	$^{207}Pb/^{235}U$	±2SE	$^{207}Pb/^{206}Pb$	±2SE	Disc (%)
M1	5	3503	43027	13005	27	42.88	4.88258	0.00556	0.32196	0.00029	0.9251	0.10999	0.00005	1799.3	2.8	1799.3	1.9	1799.2	1.7	-0.01
M2	5	1245	17551	8234	15	49.20	4.89258	0.00567	0.32303	0.00029	0.9404	0.10985	0.00005	1804.5	2.8	1801	2.0	1796.9	1.6	-0.49
M3	5	2476	25795	8483	29	36.00	4.91523	0.00595	0.32372	0.00031	0.9237	0.11012	0.00005	1807.9	3.0	1804.9	2.0	1801.4	1.8	-0.41
M4	5	1603	14585	13539	12	31.27	4.92451	0.00621	0.32404	0.00034	0.9412	0.11022	0.00005	1809.4	3.3	1806.5	2.1	1803.1	1.6	-0.4
M5	1	2582	13546	4976	11	17.55	4.93797	0.00614	0.3243	0.00032	0.9109	0.11043	0.00006	1810.7	3.2	1808.8	2.1	1806.5	1.9	-0.27
M6	1	1480	12209	8155	4	28.24	4.92908	0.00576	0.32415	0.00033	0.8374	0.11029	0.00007	1810.0	3.2	1807.2	2.0	1804.1	2.3	-0.37
M7	1	2198	14293	9886	4	22.06	4.91671	0.00593	0.32373	0.00033	0.8771	0.11015	0.00006	1807.9	3.3	1805.1	2.0	1801.9	2.1	-0.39

Notes:
[1] Radiogenic Pb
[2] Measured ratio, corrected for spike and fractionation
[3] Total common Pb in analysis corrected for fractionation and spike
[4] Corrected for blank Pb and U and common Pb, errors quoted are 1 σ absolute; procedural blank values for this study are 0.1 pg U and 1 pg Pb
Pb blank isotopic composition is based on the analysis of procedural blanks; corrections for common Pb were made using Stacey-Kramers compositions.
[5] Correlation Coefficient
[6] Corrected for blank and common Pb, errors quoted are 2 σ in Ma
The error on the calibration of the GSC Pb-U-Th spike utilized in this study is 0.22% (2σ).

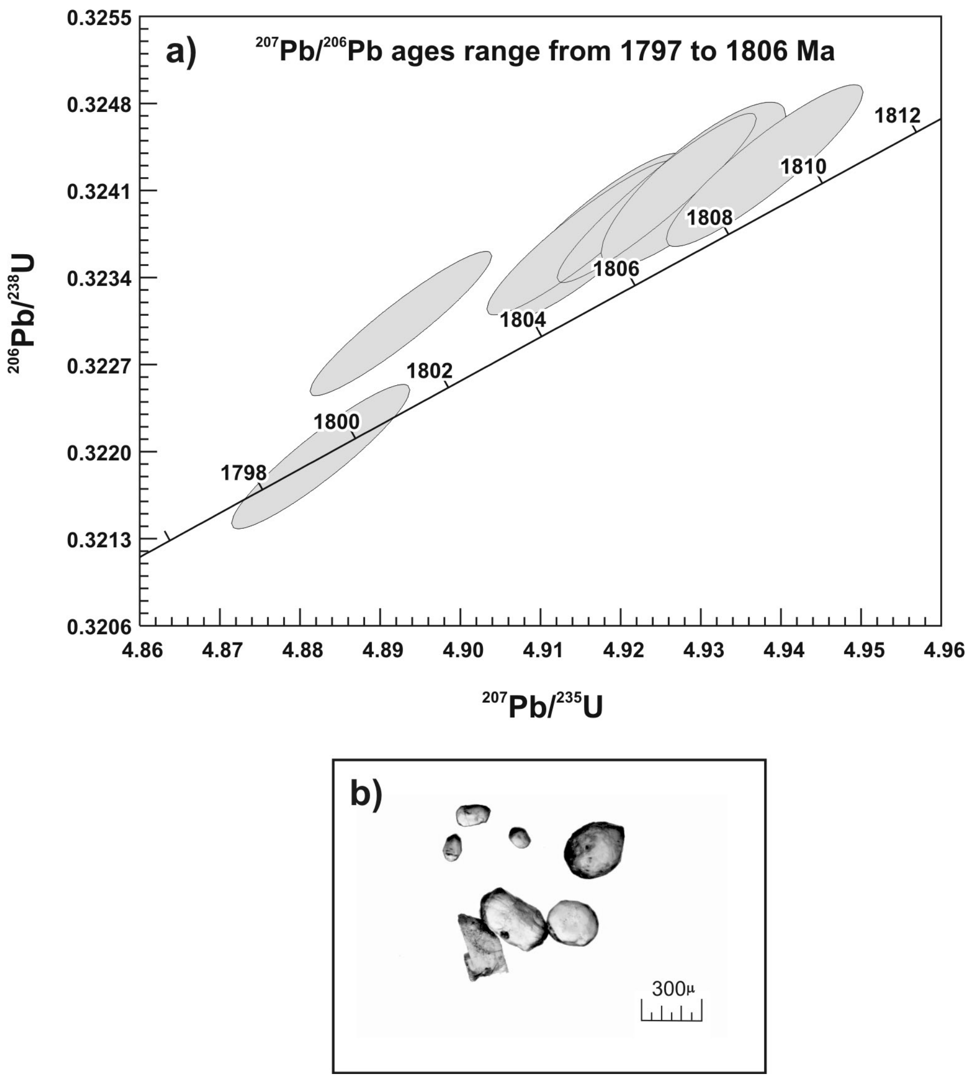

Figure GS-10-6: *a) Concordia diagram of U-Pb showing the age of monazites from an Ospwagan-like quartz-rich metasedimentary rock. Ages between 1797 and 1806 Ma are interpreted to record the time of peak metamorphic conditions; b) shows the analyzed grains.*

at 5.5 kbar (Gordon, 1989; Menard and Gordon, 1997). It is possible that the geothermometers re-equilibrated during cooling, but further analyses are required to test this hypothesis. Alternatively, migmatite temperatures may have been buffered by melting reactions such that higher temperatures could only be achieved through a loss of granitic melt (cf. White and Powell, 2002). Similar temperatures could have therefore prevailed within a considerable depth range. If the hypothesis of constant temperature at pressures of 5 to 7 kbar within the central Kisseynew Domain is valid, it presents an interesting contrast with the southern flank of the metamorphic culmination. There, Kraus and Menard (1997) inferred that the temperature gradient occurred at constant pressures between 4 and 6 kbar.

Metamorphic assemblages within the Kisseynew Domain are not strongly retrogressed. Mineral assemblages record near-peak or peak metamorphic conditions with few apparent outcrop-scale retrograde reactions. The slow cooling during uplift and exhumation of these rocks to shallow depths was either incubated by the heat from late magmatism, or occurred in the absence of free water, restricting rehydration reactions and regional retrogression. The lack of retrograde overprinting makes the determination of the peak metamorphic conditions relatively straightforward, but presents a challenge to defining the post-peak metamorphic evolution.

Economic considerations

Granulite-facies metamorphic rocks generally have limited economic potential; however, this study illustrates that high metamorphic grade serves as a first-order guide to exhumed deep crustal sections in the northeastern Kisseynew Domain, which may include sub-Burntwood strata. If correlations are validated between the high-grade Ospwagan-like rocks in the Wuskwatim Lake area and the Ospwagan type section in the Thompson Nickel

Belt, other granulite-facies areas could host similar units. Given the generally recessively weathering nature of the Ospwagan Group, occurrences of metamorphic orthopyroxene provide a broader target for exploration in this environment.

Conclusions

Metamorphic mineral assemblages in the Burntwood Group and in the meta-argillaceous sections of the Ospwagan Group are nearly identical, indicating common peak conditions in the upper-amphibolite and granulite facies, at temperatures around 775°C and pressures near 7 kbar. The basement, as well as the Ospwagan and Burntwood groups, may have had distinct metamorphic histories. Retrograde assemblages within the Kisseynew Domain are sparse. Future petrographic analyses and isotopic dating will help constrain the metamorphic pressure-temperature-time path of the diverse tectonostratigraphic sequences in the northeastern Kisseynew Domain.

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