EUG XI

Symposium SS02

Origin and Evolution of Precambrian Anorogenic Plutonism

Convenors

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SS02
Origin and Evolution of Precambrian Anorogenic Plutonism

Wednesday PO Session

SS02 : WEpo01 : PO
Mid-Proterozoic Granitoids from the Mazury Complex (NE Poland): AMCG Affinities?

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Eighty samples from eight drillings localized along the E-W Mazury Complex batholith (Bartoszyce, Filipow, Goldap, Ketrzyn, Klewno, Lanowicze, Olsztyn and Pawlowka), were studied for major and trace elements and for Sr and Nd isotopes. They show a widespread differentiation trend from monzodiorite to leucogranite, with SiO_2 contents ranging from 46% to 76%. All groups of rocks have very similar patterns in both REE and spider diagrams, which are interpreted as evidence of their consanguinity. Each drilling core has however its own characteristics when major and trace element variation diagrams are considered, which possibly reflect variable modalities of differentiation from one area to the other. In addition, all samples plot along a major trend similar to the jotunitic liquid line of descent defined in the anorthosite - mangerite - charnockite - (rapakivi) granite (AMCG) suite from Rogaland (Norway). ε_{NdT} recalculated at 1.5 Ga (age of emplacement given by U-Pb zircon data) range from -0.62 to -6.82, whereas ε_{SrT} ranges from -10 to +287. These values indicate that crustal contamination has played an important role in the genesis of these magmas. Moreover as the data plot along a single hyperbola in a ε_{NdT} vs ε_{SrT} diagram, it can be proposed that contamination resulted from a single and quite homogeneous crustal contaminant. This later could be the Svecofennian basement that is widespread in this part of Poland. In conclusion, we work on the hypothesis that the various components of the Mazury Complex derived through variable degrees of partial melting of a single and quite homogeneous source. These magma batches were contaminated at different degrees by the basement in which they emplaced, and each massif evolved independently by low degrees of differentiation.

SS02 : WEpo02 : PO
The Oldest Known Anorogenic Peralkaline Granite Magmatism in the Keivy Terrane, NE Baltic Shield

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Alkaline magmatism is abundant in the Baltic Shield. There are many tens alkaline massifs and carbonatites of Paleozoic and Proterozoic age, and only one alkaline-carbonatite massif Siilinyarvi (Finland) of Archaean age was known untill recently (Blichert-Toft et al., 1996). The Keivy peralkaline granite complex consists of vast (total exposed area - 2500 km^2) sheet-like peralkaline granite bodies, granosyenite dykes and minor nepheline syenite fault-type intrusions. Most massifs are confined to the margins of Keivy terrane and emplaced between the TTG-basement and supracrustal rocks composed mainly of dacite-rhyolite metavolcanics. The zircons from aegirine-augite-ferrohastingsite granosyenite of the Zapadnokeivskiy massif yield the U-Pb age of 2674±6 Ma, from aegirine-arfvedsonite granite of the Belaya Tundra massif - 2654±5 Ma, from nepheline syenite of the Sakharjok massif - 2613±35 Ma. These ages are the oldest known for alkaline rocks in the Baltic Shield. The Pb-Pb, Rb-Sr, K-Ar isotope systems recorded the late metamorphic events at 2.45, 2.35, 1.75, 1.65 Ga. The granites are petrologically and geochemically similar to the Phanerozoic A-type granitoids. The A-type granitoids were emplaced in noncompressive regimes either at the end of orogenic cycle (post-orogenic or post-collisional A-granitoides) or in the continental rift zones and within plate settings (anorogenic A-granitoides). On standard trace element discriminant diagrams (Pearce et al., 1984; Eby, 1990, 1992) the Keivy peralkaline granites plot as post-collisional A-granitoides. The voluminious (1000 km^3) and spatially related gabbro-anorthosite magmatism of 2.68-2.66 Ma age (Bayanova et al., 1998) can be also the result of extensional regime in Keivy region at that time and possible paragenetic (genetic?) relationship can be proposed for anorthosite-granite pair. The previously known peralkaline granites and associated nepheline syenites of the same age (ca. 2.68 Ga) from southern Superior Province (Canada) are related to subduction and have the geochemical features of M-type granitoids (Sutcliffe et al., 1990). The nepheline syenites of Keivy terrane plot within the OIB field. Previously the oldest ocean islands rocks were found in the 2.0-1.9 Ga Circum-Superior Belt of Canada and the absence of earlier examples was explained by the lack of metasomatical processes in the mantle and lower lithoshere (Blichert-Toft et al., 1996). The felsic metavolcanics of Keivy terrane reflect the geochemical features of island-arc volcanics and were erupted in the period of 2.87-2.83 Ga (Mitrofanov, Bayanova, 1999; Kudryashov et al., 1999). As the consequence of subduction were the mantle metasomatism and mantle plume formation under the Keivy terrane. Based on the Sm-Nd isotope data the Keivy peralkaline granites and nepheline syenites fall into a narrow time span of model ages - 2.81-2.79 Ga. It is suggested that the enriched mantle source for Keivy anorogenic peralkaline granites and OIB-like nepheline syenites was formed within this peroid.

SS02 : WEpo03 : PO
Magnetic Fabric and Microstructures in the Holum Granite (Vest-Agder, Norway): New Constraints on the Last Sveconorwegian (Grenvillian) Regional Deformation Phase in Southern Norway

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In the Sveconorwegian orogenic province of SW Scandinavia, abundant late- to post-tectonic granitoids intruded between c.a. 990 and 880 Ma, at the end of the Sveconorwegian (= Grenvillian) orogeny. These granitoids form two N-S trending, broad belts of plutons that are parallel to major lithospheric weakness zones dividing the Sveconorwegian province into several crustal segments (Andersson et al., 1996).

The Holum granite (Vest-Agder, southern Norway) belongs to the westernmost of these two granitoid belts. It is a magnetite-bearing, biotite-hornblende granite, that forms a N-S elongated pluton (~83 km^2), intruded in amphibolite-facies gneisses and syn-orogenic granitoids. The Holum granite has been described as an undeformed pluton and dated to 980 Ma (Rb-Sr whole-rock isochron) (Wilson et al., 1977), which is the oldest intrusion age that is available for "post-tectonic" granitoids in the area. Accordingly, in the intricate succession of structural and metamorphic events that characterises the Precambrian of southern Norway, 980 Ma has been taken as a lower limit for the last Sveconorwegian tectonometamorphic phase (Falkum, 1998).

We have conducted a structural study on the Holum granite, based on the description of macro- to micro-scale structures, and measurement of the low-field anisotropy of magnetic susceptibility (AMS) (e.g. Borradaile and Henry, 1997). The field observations show that the main structural feature in the Holum granite is a foliation of magmatic origin, roughly striking parallel to the N-S elongation of the pluton, in agreement with its proposed post-tectonic character. The AMS study reveals a magnetite-dominated magnetic mineralogy (with a bulk magnetic susceptibility ranging from 11.6 to 103.3 mSI). It displays a NNW-SSE trending pattern of magnetic foliations, that is slightly to strongly oblique to the magmatic one, and SW plunging magnetic lineations whose trajectories cut across the pluton borders. This magnetic fabric pattern, together with plastic deformation evidenced in the rock-forming minerals, indicate that the Holum granite is best seen as a late-tectonic pluton. This questions the chronology previously established for the Sveconorwegian orogeny waning stage in southern Norway.

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SS02 : WEpo04 : PO
Dyke Swarms in the Pan-African Basement from the Alpine Danubian Window: New Field and Geochemical Investigations in Southern Carpathians (Romania)

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The Pan-African Lainici-Paius basement of the Danubian window (Southern Carpathians, Romania) is composed of amphibolite facies metasedimentary rocks (quartzite, paragneiss, marble and amphibolite) covered in its central part by Silurian fossiliferous sediments and to the south-west by a Permian series. It is crosscut by three major dyke swarms that have contrasted petrography, geochemistry and age. In its central and eastern parts, the Lainici-Paius basement is cut by early leucogranitic dykes and irregular masses (c. 585 Ma, U-Pb zircon) of the Lainici-Paius dyke complex (LPDC), that represent 10-25% of the basement volume. It is only composed by monzogranitic rocks (70%-75.5% SiO_2) often pegmatitic; they contain black K-feldspar (graphite inclusions). LPDC is older than the large medium- to high-K calc-alkaline and shoshonitic plutons (c. 570 Ma; U-Pb zircon and Ar-Ar amphibole). LPDC have the most evolved isotopic characteristics (mean $^{87}Sr/^{86}Sr_{585}$ = 0.720 and εNd_{585} = -12) of the Danubian window basement rocks and represents a late-metamorphic partial melt of an old (Archaean?) crust. The pre-Silurian Motru dyke swarm (MDS) intrudes after all plutons often concordantly to the regional steep-dipping pre-Alpine schistosity. Recent field investigations on a area of 90x30 km in the central part of the Danubian window show that this swarm is composed of 1-3 m thick bodies composed of high-K calc-alkaline porphyritic micromonzodiorite to microgranodiorite (58%-66% SiO_2). Isotopic signature ($^{87}Sr/^{86}Sr_{570}$: 0.7061-0.7064 and εNd_{570} -2.6/-4; $^{87}Sr/^{86}Sr_{440}$ 0.7068 and εNd_{440} -4/-5.4) indicate the presence of both a juvenile and an old crustal component. The pre-Permian Almaj Dyke Swarm (ADS), is located in the SW part of the Danubian window. Although not yet dated (work in progress), a Variscan age is classically privileged. It is composed of high-K calc-alkaline fine-grained porphyritic (plagioclase and hornblende) microdiorite to microgranodiorite (48-65% SiO_2) and of lamprophyre dykes rich in phlogopite. Compared to BDS geochemistry, ADS appears to be more potassic. Isotopic signature indicates a mainly juvenile source in late Pan-African times ($^{87}Sr/^{86}Sr_{570}$: 0.700-0.706 and εNd_{440}: +5/+2) or a more evolved (crustal) signature in Variscan times ($^{87}Sr/^{86}Sr_{300}$: 0.704-0.706 and εNd_{300}: +1/-2). These dyke swarms, hosted in an Alpine tectonic unit, were produced in a late metamorphic Pan-African event (LPDC) and, subsequently, in two extensional late Precambrian and/or Palaeozoic episodes (MDS and ADS).

SS02 : WEpo05 : PO
Olivine-Rich Cumulate in the Pan-African Tismana Shoshonitic Granitoid Pluton, South Carpathians, Romania

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The two lowermost Alpine nappes building the South Carpathians (Lainici and Schela Danubian nappes) contain Pan-African basement rich in granitoid bodies, either calc-alkaline or shoshonitic, the latter type being illustrated by the Tismana (567 ±3 Ma; U-Pb zircon) and Novaci plutons. These two intrusions are unique in the Danubian due to:

the presence of basic strips and enclaves in various stages of hybridisation, containing clino- and orthopyroxenes; the presence of hornblende in granites; the centimetre-size megacrysts of microcline; the special morphology of zircon crystals. They constitute a continuous shoshonitic liquid line of descent from 50 to 75% SiO_2, with relatively high Sr_{567} isotopic ratios (0.7065-0.712), coupled with $\varepsilon_{Nd,567}$ from -2.5 to -6 (Duchesne et al., 1998).

The most mafic rocks in Tismana are olivine-rich cumulates, outcropping as a few lenses of several hundred metres clustered in the centre of the pluton, a unique lithology in the South Carpathians granitoid plutons. The boundary between the ultramafic rocks and the enclosing porphyritic granite is sharp. However, close to the contact, the granite displays particular rapakivi-type textures: grey-bluish cloudy plagioclase mantled K-feldspar megacrysts; cellular intergrowth in the plagioclase; abundant granophyric coronas around small euhedral K-feldspars, and coronas of biotite, amphibole, apatite ±ilmenite around ocellar quartz. These aspects point to reaction between the enclosing granitic magma and the trapped still hot ultramafic blobs.

These fine-grained (~ 2-3 mm) rocks contain 40-45 modal% olivine oikocrysts (Fo_{82-84}), 15-20% interstitial orthopyroxene (mg# 0.86-0.90), 10% brown phlogopite (mg# 0.85-0.90), 5-10% brown amphibole (mg# 0.81-0.84) and less than 10% plagioclase that has been partially reequilibrated (An_{60}). Accessory minerals are pyrrhotite with pentlandite exsolutions, Cr-rich spinel and titanomagnetite.

Microprobe data were obtained on minerals from two samples, one with 41% SiO_2 and 32% MgO, the other with 45% SiO_2 and 23% MgO. The first sample displays high temperature substitution in phlogopite; the plagioclase-amphibole thermometer give a c. 960°C temperature and the opx-cpx thermometer 970 - 1100°C. The second sample shows low temperature substitution in phlogopite; the spinel-olivine thermometer gives a c. 840°C temperature. Olivine composition (Fo_{82-84}) in both samples points to a temperature of c. 1220°C and the plagioclase composition (An_{60}) indicates a 1080°C temperature. This disequilibrium between the minerals of Tismana cumulate is testified by the fact that olivine is always in contact with phlogopite but never with opx, cpx and plagioclase. Phlogopite, always rimming olivine, is never found in inclusion into olivine. Inclusions in the latter are spinel. No reliable geobarometer can be applied in these rocks. These ultramafic olivine-rich lenses enclaved into the Tismana shoshonitic porphyritic granite are typical potassic olivine-phlogopite cumulates.

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Thursday AM Session

SS02 : THam01 : G8
Tectonic Settings of 1.65-1.4 Ga AMCG Magmatism in the Western East European Craton (Western Baltica)

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The East European Craton (EEC) was created as a single continent by the amalgamation of three crustal segments, Fennoscandia, Sarmatia, and Volgo-Uralia ca. 1.7 Ga ago. Subsequently, it underwent complex movements and interaction with other cratons until it was incorporated into the supercontinent Rodinia at ca. 1.0 Ga (e.g. Buchan et al., 2000).

This period of pre-Rodinian history was marked by voluminous within-plate, particularly by AMCG (anorthosite-mangerite-charnockite-(rapakivi)-granite) magmatism that affected almost the entire western EEC between 1.65 and 1.4 Ga. Three major stages can be distinguished:

1. Between ca. 1.65-1.58 Ga, large AMCG plutons such as Wiborg, Åland and Riga were formed in postcollisional, extensional tectonic setting that followed the major collision and formation of EEC at ca. 1.7 Ga. Spatially, these plutons associate with the thickest Palaeoproterozoic crust (cf. Korja et al. 1993).

2. The ca. 1.54-1.45 Ga AMCG magmatism appear to have mostly been controlled by large-scale EW-trending lineaments/shear zones which cut and partly inherit the Palaeoproterozoic tectonic fabrics in western EEC. These may have been a response to compressive tectonics well documented e.g. in southern Sweden (cf. Hubbard, 1975; Soderlund et al. 2000), on Bornholm and in northern Poland and additionally recorded by Ar/Ar ages of metamorphic amphiboles from the basement rocks in Lithuania and Belarus. The internal structure of some plutons and metamorphism and deformation of host rocks indicate emplacements of AMCG melts in connection with the development of the shear zones. Reflection and refraction seismics around the south Baltic Sea suggest the highly sheared mid- and lower crust (e.g. BABEL Working Group, 1993) and high Vp/Vs ratios and high degrees of crustal melting. Tentatively, paleomagnetic data and tectonic correlations between Baltica and other Proterozoic continents may suggest that collision with Amazonia is the most plausible explanation for the 1.54-1.45 Ga compessional/local extensional tectonics and reactivation of the continental crust in western EEC. I propose to name this collisional orogeny “Dano-Polonian”, best exhibited in southern Sweden, on Bornholm, and in northern Poland. 3. The later, ca. 1.4 Ga AMCG magmatism (e.g. the Varberg suite, Ahall et al, 1997) appears to have been subsequent to the Dano-Polonian orogeny and was accommodated by zones of crustal extension.

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SS02 : THam02 : G8
Two Distinct Post-Collisional Magmatic Suites in the Sveconorwegian of Southern Norway: Consequences for the Evolution of the Proterozoic Continental Lithosphere

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In southern Norway, the post-collisional magmatism is represented by two suites: 1) the anorthosite-mangerite-charnockite (AMC) suite (930 Ma) emplaced in the Rogaland Province and 2) the hornblende-, biotite-bearing granitoid (HBG) suite intruded in the Vest-Agder Province (980 to 920 Ma). Petrographical, geochemical and isotopic data indicate that they represent two distinct liquid lines of descent whose least differentiated samples, supposed to be their respective parent magmas, have an intermediate composition (SiO_2 = 50-52%). The AMC suite is alkali-calcic ferri-potassic,whereas the HBG suite is high-K calc-alkaline. The AMC suite has higher K_2O, FeOt and lower CaO, and Th contents than the HBG suite.

The two suites overlap in Sr isotopic initial ratios (AMC: 0.7029 - 0.7085; granitoids : 0.7027 - 0.7050 at 930 Ma) but epsilon Nd is higher in AMC (0 to +5.7) than in HBG (+1.9 to -4.90) (Demaiffe et al., 1986; Menuge, 1988; this work). Combined with geochemical data, this suggests that the parent magmas of the two suites resulted from the partial melting of two different sources: a LILE-depleted source (either the upper mantle or a mafic rock derived from it) for AMC and an undepleted or slightly enriched source for the HBG (lithospheric mantle or mafic rock derived from it).

Phase equilibrium data bring additional constraints and show that the parent magma of the AMC suite results from the partial melting of a lower crustal anhydrous gabbronoritic source (Longhi et al., 1999). Concerning the parent magma of the HBG suite, experimental liquids obtained at 8 kbar on the dehydration melting of a low-K garnet-free amphibolite (0.21 wt% K_2O) by Rapp and Watson (1995) are close to the parent magma of the HBG suite for CaO, MgO, FeOt, TiO_2 and the Peacock index, but much higher in Na_2O and much lower in K_2O, calling for an additional mineral such as phlogopite in the source. This hydrous potassic mafic or ultramafic source could lie either in the lithospheric mantle previously modified during the subduction period or in the lower mafic crust derived from it (Liégeois et al., 1998).

The penecontemporaneous melting of these two contrasting sources, anhydrous mafic lower crust versus hydrous mafic -ultramafic potassic crust or mantle could reflect the stratification of the lithosphere (mantle vs crust) or of the continental crust itself or may indicate that the two suites belong to two distinct lithospheric segments as formerly proposed by Duchesne et al. (1999).

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SS02 : THam03 : G8
Experimental Determination of Phase Equilibria of the Lyngdal Granodiorite (Southern Norway)

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The Proterozoic Lyngdal granodiorite (300 km2, 60-65 wt% SiO_2) belongs to a series of A-type granitoids (the Mandal Suite: Vander Auwera et al., in prep.) stretching along a major crustal lineament, the Mandal-Ustaoset Line (Sigmond, 1985). This Mandal Suite is coeval and spatially associated with the post-collisional Rogaland Anorthosite-Mangerite- Charnockite (AMC) Suite (930 Ma, Schärer et al., 1996) and shows a trend from ca. 59 wt% SiO_2 to ca. 76 wt% SiO_2. It shares many geochemical characteristics with anorogenic rapakivi-like granitoids. However, granodiorites are dominant over granites in this Suite and Vander Auwera et al. (in prep.) suggest that granites are derived by fractionation products of the granodiorites.

Crystallization experiments were conducted at 4 kb, in the temperature range 775-950°C, and at NNO on two samples of the Lyngdal granodiorite (60 and 65 wt% SiO_2) in order to constrain crystallization conditions (P, T, fO2, H_2O in melt) and test whether fractional crystallization is at work in the Mandal Suite (Vander Auwera et al., in prep.). Experiments were performed with an internally heated pressure vessel as in Scaillet et al. (1995). The choice of pressure is based on the Al-in-Hornblende geobarometer (Johnson and Rutherford, 1989) and fO2 on the stability of the assemblage titanite-magnetite-quartz which suggests an fO2 close or even higher than NNO (Wones, 1989). Experiments were fluid-saturated with various H_2O/CO_2 ratios in the fluid for each temperature.

The liquidus for both compositions is above 950°C with magnetite, ilmenite, apatite and clinopyroxene as near-liquidus minerals. Low-Ca pyroxenes stability field is restricted to low aH_2O (H_2Omelt<6 wt%) at all temperatures. Plagioclase is the sole feldspar between 775-950°C and amphibole appears at ca. 880°C for high aH_2O and breaks down to pyroxene when H_2Omelt<5 wt%.

Comparison between experimental phase equilibra and the crystallisation sequence deduced from textural observations indicates that the Lyngdal granodiorite crystallized from an H_2O-rich magma (H_2Omelt>6 wt%) at an fO2 close to NNO. However, although the experimental glass trend parallels the natural Mandal Suite, it is shifted to higher CaO and Al_2O_3. On-going experiments at different pressures will dictate whether this misfit can be ascribed to a pressure effect. The hydrous and oxidized character of the Lyngdal granodiorite contrast with the dry and reduced status inferred for the Rogaland Anorthosite-Mangerite-Charnockite series (Vander Auwera et al., 1998). This suggests that, though coeval, both suites were generated from different sources.

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SS02 : THam04 : G8
Water Contents and Differentiation of A-Type Granitic Magmas

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Recent experimental results on phase relationships in synthetic and natural granitic systems are used to constrain (1) the effect of aH_2O and fO_2 on differentiation; and (2) the water contents of A-type granitic melts. Liquidus temperatures for the Qz-Ab-Or system with minimum or eutectic compositions containing low water contents (less than 2 wt% H_2O) are shifted to higher temperatures when compared with previous estimations [1]. Thus, melts generated in the crust at high temperatures and low water activities, such as A-type granites, may contain higher water contents than previously assumed (up to 20% relative). In addition, the slopes of the liquidus curves show that adiabatic decompression produces a higher amount of melt than previously assumed (at high temperature, the increase in melt fraction by adiabatic decompression can be up to 50% higher than calculated by [1]).

Phase relations have been determined experimentally at 200 and 300 MPa as a function of aH_2O and fO_2 in four compositions showing different degrees of differentiation (2 compositions from the Wiborg batholith; 2 compositions from the Lachlan Fold Belt, LFB). As expected, the hornblende stability field is strongly dependent on the bulk composition, fO_2 and aH_2O. Reducing the fO_2 results in a decrease of the upper thermal stability of hornblende, in agreement with [2]. The crystallization of hornblende requires a water content of the melt of at least 4 to 5 wt% H_2O. Although opx is not observed in the natural assemblages of LFB, opx is a stable phase at high temperature and has probably influenced the early differentiation of the LFB granites. Preliminary data (obtained at the Ni-NiO buffer) suggest that the initial water content in the less differentiated LFB and in the Wiborg melts are between 2.5 and 4 wt% H_2O. These results are in agreement with those obtained from the liquidus curves in synthetic systems.

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Dall'Agnol R et al., *J Petrol*, **40**, 1673-1698, (1999).

SS02 : THam05 : G8
Formation of Ilmenite-Rich Cumulates by Magma Mixing: Comparisons of Mineral Chemistry in the Layered Series of the Bjerkreim-Sokndal Intrusion and the Tellnes Ilmenite Norite, Norway

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Wilson et al. (1996) presented convincing arguments that ilmenite-rich cumulates in the Layered Series of the 930 Ma Bjerkreim-Sokndal Intrusion formed by mixing residual magma with recharging more primitive jotunitic magma of related composition. During mixing, exemplified by rocks at the base of Megacyclic Unit IV, the hybrid magma temporarily found itself within the "volume" of single-phase ilmenite crystallization, resulting in a burst of ilmenite precipitation. With ilmenite precipitation, the magma returned to co-saturation with plagioclase and orthopyroxene. These mixing events were sufficiently common to produce dark layers 10-20 cm thick with modal ilmenite amounts of 50% or more, that extended across the floor of a chamber having a horizontal area of ~625 km^2 and a thickness up to 7 km. One such 10 cm layer could contain ~31,250 m^3 of ilmenite. Modal and cryptic layering in the Tellnes Ilmenite Norite "dike" is extremely hard to detect. Nevertheless bulk chemical studies of thousands of mine samples and core borings plus mineral analyses from selected specimens indicate a range of silicate compositions (An37 to An51, En65 to En81, olivine rocks En74-78, Fo71-76) similar to but exceeding the range encountered in the regression at the base of MCU IV of the Bjerkreim-Sokndal (An44 to An54, En68 to En76, Fo75). In Tellnes the most evolved rocks occur near margins of the intrusion and the most primitive rocks in the interior. In Bjerkreim-Sokndal the most evolved rocks occur at the base of MCU IV, and more primitive rocks above the base. The similar compositional ranges in the two intrusions, both associated with concentrations of ilmenite, suggest a parallel origin from similar magmas and mixing events but within chambers of different shape. A common magma source is ruled out by recent geochronology (Schärer et al., 1996). Tellnes is ~10 m.y. younger than Bjerkreim-Sokndal . For Tellnes we suggest that magma mixing and precipitation took place within a dike-like chamber. The ilmenite-rich cumulates formed either as a consequence of density sorting or by in-situ crystallization along walls. Magma recharge took place through a conduit at the end or side of the chamber so that precipitate ilmenite, with lesser pyroxene and plagioclase, all of gradually changing composition, accumulated on the bottom and walls of the chamber, whereas the residual liquid moved laterally upward and was eroded away. This hypothesis for concentration of ilmenite in Tellnes calls a) upon a process well documented in the same district, b) upon jotunitic magma which has produced chemically similar precipitates, and c) not upon an unusually oxide-rich magma, occurrence of which is in great doubt as a result of experimental studies.

Schärer, U., Wilmart, E., and Duchesne, J. C., *Earth and Planetary Science Letters*, **139**, 335-350, (1996).
Wilson, J. R., Robins, B., Nielsen, F. M., Duchesne, J. C. and Vander Auwera, J., *The Bjerkreim-Sokndal Layered Intrusion, Southwest Norway. In Cawthorn, R. G., Editor, Layered Intrusions. Elsevier Science*, 231-255, (1996).

SS02 : THam06 : G8
Geochronology of the Bandak Group and Related Rocks, S Norway, and Relationships to A-Type Magmatism and Orogenic Events in the Sveconorwegian Orogen

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In the Telemark sector of the Sveconorwegian orogen, the Bandak group unconformably overlies the Rjukan and Seljord groups, and consists of low-grade basalt and rhyolite flows, intercalated and covered with immature cross-bedded sandstone, with local conglomerate layers and angular unconformities. The Heddal group occurs in the east of the Telemark sector and consists mostly of impure metasandstone covering the Seljord group. Reliable geochronology of the Bandak group has been hampered by element mobility and inheritance problems. New SIMS U-Pb data were acquired on zircon in volcanic rocks and clastic sediments. In Rödberg, a dacite directly overlying quartzite of the Seljord group and attributed to the Bandak group yields a crystallization age of 1169 ±9 Ma (11 analyses) and displays 1.7-1.5 Ga inheritance (3 analyses). The data implies that the Bandak group is part of the widespread 1.19-1.15 Ga mafic to felsic magmatism occurring mainly in the Telemark-Bamble terrane and locally in the Rogaland-Hardangervidda terrane, but notably absent in the Idefjorden terrane (SW Sweden). This magmatism includes charnockitic plutons of A-type geochemical signature. It shortly pre-dates the early-Sveconorwegian 1.15-1.10 Ga high-grade metamorphism and deformation recorded in the Bamble sector. The geotectonic setting and significance of this magmatism is unclear, but it may relate to early migration or accretion of terranes at the margin of the Fennoscandian shield. In Veggli, a rhyolite situated below metasandstone of the Heddal group yields a crystallization age of 1159 ±8 Ma (15 analyses). In Haglebu, a metasandstone of the Heddal group has detrital zircon populations at 2.86-2.41 and 1.94-1.11 Ga (33 grains) and in Kalhovd, in the hanging wall of the Mandal-Ustaoset shear zone, a metasandstone from the top of the Bandak group has populations at 2.85-2.74 and 2.00-1.05 Ga (40 grains). These sediments display very similar zircon age distributions and can be correlated.

They were deposited after 1112 ±20 and 1054 ±22 Ma respectively, thus largely after the 1.17-1.16 Ga volcanic rocks and after the early-Sveconorwegian orogenic phase. They may reflect formation of intra-orogenic pull-apart or extensional basins. In the Rogaland-Hardangervidda terrane, supracrustal rocks of the Breive-Valldal region display a rhyolite unconformably overlain by a basalt and sandstone sequence. Two rhyolite and one porphyry samples yield crystallization ages of 1261 ±9 Ma (Valldal, 11 analyses), 1264 ±4 Ma (Hovden, 16 analyses) and 1275 ±8 Ma (Breive, 16 analyses). These rocks are significantly older than the volcanic rocks of the Bandak group and emplaced at the poorly defined onset of the Sveconorwegian period. A sandstone interlayered with low-grade basalt flows (Sandvatnet) displays detrital zircon populations at 2.95-2.71, 2.17-1.75 and 1.62-1.21 Ga (40 grains). The sediment was deposited after 1211 ±18 Ma. The age distribution of zircon in this sample is distinct from the ones in the Bandak group.

SS02 : THam09 : G8
2.4 Ga A-Type Granites of the Kainuu Region, Eastern Finland: Characterization and Tectonic Significance

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In the Kainuu region of eastern Finland, several discordant granite stocks and associated silicic dyke rocks with a conventional U-Pb zircon age of 2.435 ±0.012 Ga are found intruding the Neoarchaean metamorphic bedrock of the northeastern Fennoscandian Shield. The stocks are dominated by a leucocratic, pink biotite granite that is distinctly porphyritic with tabular to ovoid alkali feldspar megacrysts up to 5 cm in diameter. Some of the megacrysts are mantled by albite/oligoclase rims (rapakivi texture). Accessory minerals include, besides ubiquitous fluorite, allanite, zircon, titanite, magnetite, apatite, and secondary chlorite.

Geochemically, the 2.4 Ga Kainuu granites have high SiO_2 (72 to 78 wt.%), K_2O/Na_2O (0.6 to 1.7), and Rb/Sr (up to 40). They are mildly peraluminous (A/CNK 0.97 to 1.22), show moderate enrichment in Fe relative to Mg (FeO_{tot}/MgO 1.8 to 5.2), have high Ga/Al (10000*Ga/Al 2.2 to 5.2), and can thus be classified A-type. Whole rock Nd isotopic ratios are indicative of slightly negative initial ε_{Nd} (at 2440 Ma) values of -2.5 to -1.5 and depleted mantle model ages (DePaolo, 1981) of 2.8 to 3.3 Ga.

In terms of their petrography and elemental geochemical composition, the 2.4 Ga Kainuu granites are much like the classic anorogenic ca. 1.6 Ga rapakivi granites of southern Finland. In addition, they are coeval with tholeiitic layered mafic intrusions of the adjacent Koillismaa-Peräpohja region further to the north and, together with the layered intrusions, thus form a bimodal magmatic association related to early Paleoproterozoic rifting of the Archaean part of the Fennoscandian Shield. Initial Nd isotopic ratios of the layered mafic intrusions (Iljina, 1994; unpublished data by the first author) and the Kainuu granites are quite similar and reflect interplay of protoliths in the Neoarchaean lower crust and subcontinental mantle.

DePaolo DJ, *Nature*, **291**, 193-196, (1981).
Iljina M, *Acta Universitatis Ouluensis*, **A258**, 158 p, (1994).

SS02 : THam10 : G8
Mineralogical Peculiarities and Thermobarometrical Assessment of Intermediate Magma Chamber beneath a Post-Orogenic Granite-Lamprophyre Ring Complex: Implications to Fractionation of Shoshonitic Magmas at Mid-Crustal Level

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During the Svecofennian post-collisional event, small P-, F-, Ba-, Sr- and LREE-enriched bimodal shoshonitic intrusions invaded hypabyssal levels of the svecofennian crust. The 1.8 Ga Åva ring-complex is one of three bimodal shoshonitic ring-complexes situated along a shear zone in SW Finland. The ring-complex is approx. 7 km across and comprises hundreds of ring dykes containing coarse porphyritic (HiBaSr) granites along with shoshonitic pillows. The granites are cut by shoshonitic lamprophyres in a radial pattern. Several different mineral assemblages were distinguished in the granite. Two deep-seated generations of Hbl, both coexisting with Sph, Bt, Qtz, ±Cpx occur as inclusions encapsulated within the K-flsp megacrysts. PT-assessment (Hbl-Pl-Qtz thermobarometry and two-Flsp thermometry) indicates that the most-deep seated, iron-rich assemblage (Fe#=Fe/(Fe+Mg)=70-90) was formed under pressures between 7 and 8 kbars and Tmin=750-840°C. Another assemblage is characterized by broad mineral-chemical variations along the following major substitution shemes: $(Fe,Mg)_2$+VI+Si = AlVI+AlIV (Al-Tschermak) in Hbl and Bt and, additionally, a few vacancy-creating substitutions in micas. Most of the substitutions display compositional gaps presuming that more than one generation of the mafic hydrous silicates are present. More iron-rich generations (Fe#=62-65) were formed under relatively elevated mineral-forming conditions (6-7 kbars) at the temperature ranging from 840 down to 740°C, while iron-poor varieties (Fe# 45-50) have yielded P=4-5 kbars, T=740-760°C. These changes are interpreted to reflect the beginning of magma rise accompanied by step-wise oxidation that facilitated precipitation of Fe-Ti oxides and hence led to decreasing in Fe-content in the hydrous silicates of the second generation. Pressures estimated from mafic cumulates of the intrusion indicate that crystallisation of the cumulus minerals (Cpx, Opx, Bt, Hbl, Pl, Ap) took place within the range determined for the mineral inclusions in K-flsp megacrysts (4-6 Kbar). However, the initial temperatures obtained for the cumulate assemblage are higher, ranging from 940°C (two-Px thermometry, QUILF), down to 780°C (Hbl-Pl-Qtz equilibria). The latter corresponds to the re-equilibration at the last stage of fractionation. These results evidence that during the post-collisional time, the crust was intruded in pulses by shoshonitic magmas that differentiated in the middle crust (about 4-7 kbar). Remnants of this material have been found as relics in 1.63 - 1.58 Ga anorogenic rocks in southern Finland.

SS02 : THam11 : G8
Petrogenesis of Norite Dike, Isua, West Greenland

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The Isukasia area in the Archean block of West Greenland is important because it contains some of the best preserved early Archean (>3.6 Ga) rocks. The Isua Supracrustal Belt surrounds one of the least deformed parts of the area. A set of c. 30 m wide norite dikes trending E-W has been sampled from this area during the summer of 1999. These dikes have earlier been dated by zircon ion microprobe to ~ 3.5 Ga (Nutman et al., 1997). The primitive nature (MgO ~ 20%) of these dikes makes it possible that evidence for early Archean mantle processes and mantle isotopic compositions are preserved. They have well preserved igneous textures of cumulus orthopyroxene (grain size app 1-2 mm in diameter) with inclusions of olivine and chromite. They also have cumulus clinopyroxene and olivine (a few percent). Intercumulus mineral growth by trapped liquid and adcumulus diffusion is inferred, the latter constructing poikilitic texturing of plagioclase. REE-patterns are subparallel with La/Lu ~ 4, with abundances varying from 3-6 times chondrites in the HREE and 12-22 times chondrites in the LREE. Eu/Eu* have values from 0.84-1.06. The abundance and Eu-anomaly variations can be explained by trapped liquid vs. adcumulus growth behaviour. This is supported by variations in Ce vs. Zr. Further REE-pattern modelling allows for a REE-pattern estimation of the initial magma. Olivine-liquid, orthopyroxene-liquid, and chromite-liquid equilibrium calculations allows for construction of an initial magma composition. A three-point Pb-Pb correlation line with a slope age of c. 3.5 Ga has been constructed from a multiply leached plagioclase. Although it is in excellent agreement with the published ion probe age, the significance of this age is yet to be determined. This is because Pb concentrations in the rocks (3-8 ppm) are high for mantle-derived magmas, and crustal contamination or other open-system behavior must be considered. However Sm/Nd isochrons from whole rock and mineral separates will allow another estimation of the age and an initial ε_{Nd}-value.

Nutman et al, *Chemical Geology*, **141**, (1997).

SS02 : THam12 : G8
Afro-Australasian Precambrian Anorogenic Magmatism as Indicators of Supercontinental Fragmentation

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Although there is some controversy concerning the exact position of cratonic nucleii in the assembly of the Rodinian supercontinent, there is ample evidence in the geological record for widespread Neoproterozoic supercontinental fragmentation around 830 - 750 Ma based on anorogenic plutonism in Africa, India, Australia and East Asia. For instance, Neoproterozoic K- and Na-rich granitoids in the Malani igneous province northwest India, Seychelles, Madagascar, Namibia, and the Lufilian Belt Zambia, all point to possible plume-related magmatic underplating or sub-crustal mantle delamination during supercontinental break-up. Some of the earliest fracturing of the Congo craton, with Neoproterozoic rift sedimentation coupled with bimodal magmatism, may have commenced as early as ca 920 Ma. Similarly, in South China, Western Laurentia and Australia, there is evidence for anorogenic granitoid magmatism and mafic dyke intrusion between 830 and 750 Ma. In some areas, e.g. Namibia, similar-aged carbonatite emplacement can be linked to rift evolution, and perhaps was a major contributor of CO_2 to succeeding carbonate platform deposition. There is, however, limited controversial evidence for supercontinental fragmentation in the Mesoproterozoic (~1.5 Ga) witnessed by anorogenic rhyolites/trachytes in central Africa associated with rifts systems developed in Eburnian crust, during pre-Kibaran times. Likewise, anorogenic magmatism in the mid-Paleoproterozic in southern Africa and northwestern Australia may ultimately point to rifting and disintergration of an Archaean-Early Proterozoic supercontinent.

SS02 : THam13 : G8
Petrogenesis of Neoproterozoic Granitoids and Related Rocks from the Seychelles: Anorogenic vs. Andean-Arc Origin

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The Neoproterozoic (700-800 Ma, dominantly 752 ±4 Ma) magmatic rocks of the Seychelles archipelago consist mainly of undeformed and unmetamorphosed, metaluminous, monzogranites and granodiorites. Both subsolvus, and a probably lesser volume of hypersolvus granitoids are present. Coeval dolerite dykes, dominantly olivine tholeiites, crosscut these granitoids; field relations suggest evidence for complex interactions between granitoid and doleritic magmas, resulting in a variety of intermediate rocks that occur as irregular masses and enclaves. This is supported by compositional patterns in which major, minor and trace element concentrations of intermediate rocks plot as linear arrays between dolerites and granitoids. Two groups of granitoids can be distinguished based on colour, chemistry and isotopic signature: Mahé Group (MG) granitoids, including all those exposed on Mahé and Ste. Anne islands, and a small portion of Praslin, are grey, with relatively low LILE and primitive isotopic signatures that cluster at $\varepsilon_{Nd\ 750}$ = +2.85 ±0.17 and I_{Sr} = 0.7031 ±8, although some samples with impossibly low I_{Sr} <0.700 were likely affected by open system processes. Praslin Group (PG) granitoids, exposed on Praslin, La Digue, Fregate, Marianne and numerous smaller islands, are characteristically red to pink, with Rb >180 ppm, U >4.2 ppm, Th >20 ppm, Pb > 30 ppm, and correspondingly evolved and variable isotopic signatures: $\varepsilon_{Nd,\ T}$ = +0.80 to -3.83; $I_{Sr,\ T}$ = 0.7072-0.7263. Petrographic, chemical and isotopic relations suggest that PG granitoids may have been more highly affected by hydrothermal or late-magmatic alteration compared to the MG. Both MG and PG granitoids appear to have been derived from a mixed source dominated by a juvenile, mantle-derived component, with variable amounts of an ancient, possibly Archaean, silicic contaminant or source constituent. Potential source materials are unexposed in the Seychelles, but the juvenile component may resemble ~750 Ma intermediate-mafic metavolcanic rocks of NW Madagascar or NE India; candidates for the ancient silicic component, whose signature is slightly enhanced in PG granitoids, may be represented by 2.5-3.3 Ga tonalitic gneisses of the Banded Gneiss Complex in Rajasthan (NW India) or by similar materials present in central-northern Madagascar. Seychelles dolerite dykes show variable Nd and Sr isotopic compositions ($\varepsilon_{Nd\ 750}$ = +5.46 to -0.87; $I_{Sr\ 750}$ = 0.7021-0.7061) that can be modelled as basaltic magmas derived from depleted mantle, variably contaminated (0-15%) by Archaean silicic crust. All extant petrologic, petrographic, geochemical, isotopic and chronologic data for Neoproterozoic magmatic rocks of the Seychelles, coupled with palaeomagnetic data indicating its position at the margin of the Rodinia supercontinent at ~750 Ma, are at least consistent with, if not demonstrative of, a continental- or Andean-arc setting. We argue, therefore, that the conventionally accepted notion of an extensional (i.e. rift or plume) setting for Seychelles magmatism is vulnerable.

SS02 : THam14 : G8
Post-Collisional, Post-Orogenic, Anorogenic, Transtensional Alkaline Magmatism: The Tuareg Shield Contribution

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Even though sometimes in small volumes, alkaline magmatism is ubiquitous and constitutes either the latest magmatic event of an orogeny or is frankly anorogenic. It is often preserved as high-level manifestations (subvolcanic and/or volcanic). Dramatic chemical and tectonic changes lead some authors to consider alkaline magmatism out of its regional context and linked to mantle plumes. Taking the Tuareg shield case study, we would like to emphasize that alkaline magmatism is actually related to basement characteristics and provides major evidence for the tectonic regime prevalent during its emplacement, otherwise difficult to decipher.

The Tuareg shield (500 000 km^2) resulted from accretion of some twenty terranes onto or along the East Saharan craton to the east during the 750-525 Ma period with final compression during the 630-525 Ma period due to the West African craton pushing from SW and marked by a general tectonic escape to the north. Each collisional event induced early regional metamorphism, followed by high-temperature metamorphism accompanying high-K calc-alkaline batholiths and large horizontal transpressional movements that characterize the protracted post-collisional period.

During or just after ultimate uplift, late transtensional movements along pre-existing mega-shear zones resulted in half-graben development filled up with alkaline rhyolite ignimbrites and associated sediments, dyke swarms and ring complexes. Datings of the alkaline magmatic episode evidence diachronism from c. 595 Ma to c. 525 Ma, indicating progressively hindered movements along mega-shear zones. This alkaline magmatic episode can be considered as late post-collisional or post-orogenic, as evidenced by slightly older unroofing, changes in tectonic regime and composition, compared with post-collisional high-K calc-alkaline magmatism, though it took place mostly before orogeny was completed within the whole shield.

The Pan-African orogen was afterwards sealed by Ordovician Tassilis sandstone deposition. Remaining since the Cambrian in intraplate setting within Africa, the Tuareg shield was affected by three major alkaline magmatic episodes: Aïr ring complexes, dykes and lavas at c. 410 Ma, Permian-Jurassic syenite-carbonatite Tadakh province and late Tertiary-Quaternary Hoggar province. All these and previous alkaline magmatic episodes in the Tuareg shield took place along transtensionally active shear zones located along rigid cratons or terranes. Despite their apparent variability, they yield large geochemical and isotopic similarities, involving juvenile sources not or slightly contaminated by old lower continental crust.

Mantle source of alkaline magmatism, enriched from below and probably located at the asthenosphere / lithosphere boundary, suffered melting events when lithospheric stresses applied on plate boundaries were channelled along pre-existing lithospheric-scale mega-shear zones. These conditions are most often met, although not exclusively, at the end of the post-collisional period and during intraplate deformation.

Thursday PM Session

SS02 : THpm21 : G8
U-Pb and Argon-Geochronology of the Proterozoic Mazury Complex, NE Poland

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The Mazury complex (MC) is 200 km long E-W trending belt of an anorthosite-mangerite-charnockite-granite (AMCG) suite, located in the westernmost part of the East European Craton (e.g. Wiszniewska et al, 2000). Three anorthosite-norite bodies have been recognized in the MC: Kêtrzyn, Suwalki and Sejny bodies. These bodies are emplaced into granulites and granitoids correlated with Svecofennian rocks (1.85 Ga). Claesson et al. (1995) dated two quartz monzonites from the MC near Goldap with U-Pb analyses on zircons with ages at 1502 Ma and at 1499 Ma. The Fe-Ti-V and Fe-Cu-Ni-Co deposits of the Suwalki intrusion have Re-Os isochrone ages of 1.559±37 Ma and 1.556±94 Ma, and high initial $^{187}Os/^{188}Os$ reflecting a crustal component in the source rock (Morgan et al, 2000). New U-Pb analyses on single zircons and titanite fractions from drilling cores allow to separate three distinct episodes of igneous activity lasting 50 Ma: (I) A monzodiorite (jotunite) of the Sejny anorthosite massif is dated with an concordant zircon at 1548±7 Ma, which is in accordance with Re-Os ages of the ore deposits in the Suwalki anorthosite massif. (II) A monzodiorite-tonalite of Krasnopol 6 is dated with a subconcordant zircon at 1525±4 Ma ($^{207}Pb/^{206}Pb$ age) and with subconcordant titanite at 1525±25 Ma ($^{207}Pb/^{206}Pb$ age), which proves a rapid cooling below 550°C. The Bartoszyce quartz monzonite is dated with 3 concordant zircons at 1522±2 Ma. (III) The youngest episode is represented by the Boksze diorite (E´of Suwalki massif), which is dated with an concordant zircon at 1513±4 Ma. The difference between U-Pb ages of titanite and Ar-Ar ages of biotite of 100 Ma (Ar-Ar ages:1435±8 Ma, Boksze; 1425±8 Ma, Krasnopol 6) suggest, that we are dealing with slow cooling rates in the range of 2°C/Ma. Because slow cooling shifts the “closure temperature” to lower values, the obtained Ar-Ar ages could represent “cooling ages” with a corresponding “closure temperature” below 300°C. The 1548 to 1513 Ma protoliths of the MC are coeval with those of the Salmi complex in western Russia (Amelin et al. 1997). The new ages allow correlation of the MC with AMCG complexes of western Russia, southern Finland, Estonia and Latvia.

Amelin YA, Larin AM, Tucker RD-, *Contrib. Mineral. Petrol.*, **127**, 353-368, (1997).
Claesson S, Sundblad K, Ryka W, Moczydlowska M, Reinfark R, *MAEGS-9 abstr. Vol*, 21
Morgan JW, Stein HJ, Hannah JL, Markey RJ, Wiszniewska J, *Mineralium Deposita*, **35**, 391-401
wiszniewska J, Wybraniec S, Bogdanova S, *31 IGC abstr. Vol*

SS02 : THpm22 : G8
Anorogenic Magmatism in the Western Part of the East European Craton: Northern Poland, Southern Lithuania and NW Belarus

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A chain of magmatic bimodal intrusions of predominating granitic composition extends eastwards from northern Poland and southern Lithuania into NW Belarus. Those bodies crosscut lithologies of several Proterozoic granulite and amphibolite facies domains, which have been developed separately before their final amalgamation at ca. 1.7-1.66 Ga (Bogdanova et al., 1996).

The Mazury complex in Poland and Lazdijai (Veisiejai) complex in Lithuania appear to belong to the same AMCG magmatic suite displaying all varieties of rocks ranging from anorthosites and gabbro to rapakivi granites. Those are mostly peralumineous rocks, which have been originated from different magma batches or influxes of the same magma chamber as it is indicated by their geochemistry. They display almost identical trace and rare earth element patterns (Skridlaite et al., 2000). The porphyritic granites from the Grodno area in Belarus may be assigned to the same AMCG suite according to their appearance and geochemistry. Several U-Pb zircon datings on the rapakivi granites of the Mazury Complex have given the same ca. 1.5 Ga age (e.g. Claesson, 1996). Titanomagnetite and sulfide ores in the gabbro-anorthosites of the Suwalki massif belonging to the Mazury complex yield Re-Os ages of ca. 1.56 Ga (Morgan et al., 2000).

The Kabeliai complex in southeastern Lithuania and the Mosty complex in NW Belarus are dominated with porhyritic biotite granites and quartz-monzonites, which are metalumineous and have A-type characteristics. These granitoids of ca. 1.5 Ga age (U-Pb zircon datings, Sundblad et al., 1994) contain a Cu-Mo mineralization of ca.1.49 Ga age (Re-Os method, Stein et al., 1999). Comparative mineralogical and geochemical studies of the rapakivi granites indicate that their origin is connected with extensional tectonic settings by melting of pre-existing (lower) continental crust. The studied granites plot in the Within Plate Granite and Post-Collisional Granite fields. In spite of some minor variations in age, they were formed ca. 1.6-1.5 Ga ago and clearly post-date the last orogeny in the western part of the EEC.

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SS02 : THpm23 : G8
2.4-2.5 Ga K-Rich Granites of the Central Aldan Shield (Eastern Siberia)- Evidence of Anorogenic Plutonism or Post-Collision Setting?

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The Early Palaeoproterozoic (2.4-2.5 Ga) extensional tectonic regime accompanied by anorogenic plutonism occurred in a number of Precambrian terrain's (SE Africa, Baltic Shield, Sino-Korean Craton). The K-rich granites of this age having specific geochemical characteristics of A-granites have been established in the western Aladdin Shield.

According to the geological and geophysical data, the Aldan Shield is subdivided from west to east into the Olekma granite-greenstone terrain (OGGT), the Aldan granulite-gneiss terrain (AGGT) and the Batomga granite-greenstone terrain (BGGT). The geological image of the Aldan Shield is defined by the widespread development of the thrust structures. The OGGT and AGGT were juxtaposed later 3.0 Ga during the thrust development forming the N-S trending 70-100 km wide Joint Zone that was experienced metamorphic reworking in the Early Proterozoic.

K-rich granites dated at 2522±2 Ma, 2487±5 Ma, 2423±28 Ma and 2398±4 Ma are dominant intrusive rocks developed within the Joint Zone. Granites form a tectonic lenses up to 500 m wide among the amphibolite- and granulite-facies gneisses and are metaluminous to slightly peraluminous in composition. Features like high total alkalis, total Fe, low CaO and MgO, high Nb, Y, Zr and REE abundances are typical for A-type granitoids. These granites belong to A2 subtype of Eby (1992). Negative epsilonNd(T) values (-10 - -2) indicate crustal sources of granites. Sm-Nd model ages of these granitoids are strongly correlate with crustal residence age of country tonalitic and granitic gneisses. Granites spatially located within the western Joint Zone close to the OGGT are characterised by TNdDM at 3.3-3.1 Ga (the main crust-forming events of the OGGT are 3.1-3.0 Ga and 3.5-3.3 Ga (Salnikova et al., 1996)) whereas those located closer to the AGGT have an older TNdDM at 3.6-3.5 Ga (the crust-forming events in the north-western AGGO are 3.8-3.5 Ga (Salnikova et al., 1996)). The youngest Sm-Nd model ages at 3.0 Ga have been detected in granites from the south part of the Joint Zone.

The main problem which we emphasise now what is a real tectonic position of these granites? What is a time gap between its emplacement and preceding collision event? Are 2.5-2.4 Ga K-rich granites of the Aldan Shield belong to anorogenic granitoids or related to post-collision setting? Therefore the only future investigations forwarding to revealing the precise age limits of the main thrust-forming events will allow establish the Early Palaeoproterozoic episode of anorogenic plutonism within the Siberian Craton.

SS02 : THpm24 : G8
Precambrian Anorogenic Complexes of Southern Margin of the Siberian Craton

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Two main stages of plutonic anorogenic activities related to extensional processes have been distinguished at the southern margin of the Siberian craton. The Paleoproterozoic magmatic complexes are represented by the North-Baikal (Akitkan) volcanic-plutonic belt (1820-1870 Ma) composed of rapakivi, rapakivi-like granite and associated acid volcanics (Neimark et al., 1998), as well as charnockite (1860-1880 Ma, Aftalion et al., 1991) and rapakivi-like granite (1860-1870 Ma, unpublished author's data) of the Sharyzhalgai massif. Rare thick mafic dikes of the same age are present in the volcanic-plutonic belt. All mentioned granites have A-type granite geochemical affinities, differing in some details. Magmatic and metamorphic events of this age are supposed to be related to postcollisional extension. Mafic dike swarms with age 850-880 Ma (Gladkochub et al., 2000) are widespread along the southern margin of the Siberian craton. Dyke distribution is highly variable, from rare (<5 dykes/km) to common (10 dykes/100 m). According to geochemical affinities mafic dikes can be divided into two groups: one of mainly tholeiitic character, and other one corresponding to sub-alkaline series. Incompatible-element abundance patterns confirm that parent magmas for these mafic dikes were produced by combination of partial melting (12-25%) of depleted in LREE spinel peridotite and following crustal differentiation. The diabases geochemically are comparable to the mafic volcanics, typical of intracontinental rift zones. Dike swarms are regarded as indicators of Rodinia breakup.

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SS02 : THpm25 : G8
Geochemical Constraints on the Petrogenesis of the O'okiep Intrusive Rocks (Namaqualand, S. Africa): A Lower Crustal Mafic Source

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The Koperberg suite in the O'okiep district (Namaqualand, South Africa) is made up of rocks of the anorthosite suite and includes Cu-bearing sulfide deposits. More than 1700 small intrusions, scattered over an area of 3000 km2 were emplaced ca 1030 Ma in granulite facies conditions at the waning stages of the Kibaran/Namaquan orogeny (Klondykean Episode). The suite of rocks is dominated by andesine anorthosite and comprises biotite diorite, leuconorite, norite, hypersthenite, as well as rare magnetitite and glimmerite. These intrusions slightly post-date the emplacement of the Rietberg granite (1037 ±16 Ma), itself younger than the Concordia and Kweekfontein foliated granites (Clifford & Barton, in prep). A geochemical study (major and trace elements) of 37 representative rock samples together with mineral separates (22 plagioclases and 2 apatites) permits to conclude that: (1) The Koperberg anorthosites and related rocks are cumulates, including hypersthenites, glimmerites, and magnetitites. The REE geochemistry of the cumulates is mostly controlled by their apatite content, irrespective of the petrographic type. Inversion of plagioclase composition using appropriate partition coefficients show that they derive from jotunitic melts; (2) The Koperberg series includes jotunites, which are identified geochemically as primitive jotunites, similar to those found as chilled margin to several intrusions in the Rogaland anorthosite province and supposed to be the parent magmas of andesine anorthosites (Vander Auwera et al., 1998). This constitutes the best unambiguous evidence that the Koperberg rock series belongs to the massif-type anorthosite kindred (AMCG suite). Jotunite magma derive from the melting in granulite facies conditions at high pressure (11-13 kb) of a 2-pyroxene plagioclase rock (Longhi et al., 1999). This strongly corroborates the crustal source origin, already deduced from Sr and Nd isotope systematics (Clifford et al., 1995) ; (3) The Rietberg granite is geochemically very similar to charnockites associated with massif-type anorthosites, except for a higher mg#. Rietberg and Concordia granites show a potassium-rich character, irrespective of their age. This is best explained through partial melting of juvenile crust in post-collisional settings (Liégeois et al., 1998). It is good evidence of a mafic igneous nature of the crustal source in that area; (4) In contrast with most massif-type anorthosites which show evidence of a polybaric crystallization, the Koperberg anorthosites and related rocks are produced through crystallization in a magma chamber at medium pressure (3-5 kb), followed by forceful injection of the cumulate crystal mush in steep structures.

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SS02 : THpm26 : G8
The Paleoproterozoic, Anorogenic Wangtu Granite from NW Himalaya, Suttei Valley, India

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The Himalayan orogenic belt is characterised by ongoing crustal processes involving large-scale deformation, remobilization and metamorphism of older crust. The Higher Himalayan Crystalline (HHC) represents a 15-20 km thick NE-dipping intracontinental ductile shear zone marked by progressive regional metamorphism in an inverted sequence. Numerous granitic bodies intrude the HHC. The Wangtu granite is a pre-Himalayan body, which contains numerous xenoliths of biotite schist and banded gneiss. The undeformed portion of the Wangtu granite is monotonous, fine- to coarse-grained, locally porphyritic, and is exposed near the Wangtu Bridge. It is dominated by plagioclase with lesser K-feldspar, quartz and biotite, with accessory apatite, zircon and opaques. Locally, epidote replaces plagioclase as a result of fluid activity during deformation and metamorphism. A few feldspar crystals show sericitization, indicating retrogression. Major element analysess indicate that all the Wangtu granitoids are peraluminous and peralkaline with SiO_2 varying between 63-73%. On a Rb vs Y+Nb discrimination plot they granitoids fall in the within plate granite field supporting an anorogenic origin. Conventional U-Pb TIMS zircon dating indicates an age of 1866 ±10 Ma, whereas, SHRIMP U-Pb zircon dating indicates a crystallisation age of 1865 ±4 Ma for magmatic zircons (rims and small prismatic crystals). Some zircons contain older inherited cores (3000 Ma and 2180 Ma) implicating an Archean to Paleoproterozoic crustal component in granitoid petrogenesis. It is thought that magmatism occurred during Paleoproterozoic extension within what is now the Himalayan orogenic belt.