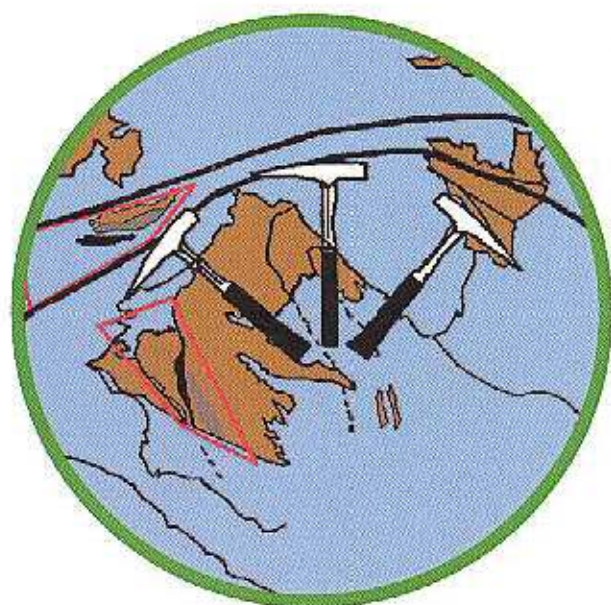


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**Annual Meeting of IGCP Project 376
"Laurentia-Gondwana connections before Pangea"**



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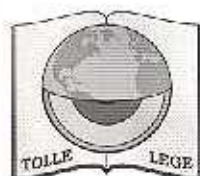
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(Laurentia-Gondwana connections before Pangea)**

Extended Abstracts

Badajoz (Spain), 26 September – 3 October 1999

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**DEVELOPMENT OF AN UPPER PALAEOZOIC
COMPOSITE FLOWER STRUCTURE ON THE
NORTHERN OSSA-MORENA CADOMIAN
BASEMENT (IBERIAN MASSIF):
THE MEGASTRUCTURE OF ASSUMAR
(NORTHEAST ALENTEJO, PORTUGAL)**

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The Megastructure of Assumar comprises an extensive and representative outcrop of the Ossa-Morena Cadomian basement characterized by a sedimentary and volcanic upper Proterozoic succession ("Seric Negra") which is unconformably overlain by upper Proterozoic/Lower Cambrian felsic volcano-sedimentary series (Freixo-Segovia Volcano-Sedimentary Complex) and by Lower Cambrian platform sequences (Detritic-Carbonate Cambrian of Assumar). The upper Proterozoic "Seric Negra" were affected by a deformation event associated with intermediate to low-grade metamorphism which does not affect the overlying uppermost Proterozoic/lowermost Cambrian stratigraphic record and the pre-Variscan granitoids (Barreiros granitoid complex and Barquete-Bedanais-Aguilh3o granitoid lineament).

The Variscan continuous deformation within the Megastructure of Assumar is characterized by composite flower structures built along sinistral strike-slip fault systems, consistent with a transpressional setting.

Despite the scarcity of geochronological and geochemical information, which inhibits the establishment of definitive correlations, one can recognize affinities between the tectonostratigraphic and metamorphic record of the Megastructure of Assumar and the Olivenza-Monesterio antiform (Spain), mainly based on field and petrographic studies.

**UPPER DEVONIAN PALYNOFORMS OF
NE SECTOR OF TR3S-OS-MONTES
(CENTRAL IBERIAN ZONE)**

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The lower parautochthonous variscan sequences occur in the NE sector of Tr3s-os-Montes, near the boundary with the subzone Galicia-Tr3s-os-Montes. The geology is characterized by the structuring and emplacement of a pile of thrust sheets, well exposed in the Morais and Braganca Massifs, which together with the Galicia Massif creates a sequence of sheets implanted on the autochthonous of the Central Iberian Zone (CIZ).

The bases of the lithostratigraphic succession of the autochthonous of the Braganca region was established by Ribeiro (1974) and then modified and reviewed by Meireles *et al.* (1995), Meireles (1997) and Ribeiro & Pereira (1997). The succession is mostly composed by Ordovician quartzites with iron bands and shales, followed by an amalgamated unit mainly of Silurian age composed, at the bottom, of black phyllites and greywackes with quartzites, limestones and limestone intercalations, and at the top, by a volcanosedimentary complex (purple shales and bimodal volcanics) interbedded in shales, quartzites and limestones. A poorly dated flysch unit of Upper Devonian age also occurs. It has been referred as the Gimonde Formation (Pereira *et al.*, 1982).

The aim of the present work is to investigate the palynological contents of the Gimonde Formation, located in the transition autochthonous-lower parautochthonous sequences of the Braganca Massif. This unit is characterized by shales and greywackes, rich in plant debris, of Upper Devonian to Lower Carboniferous age (Teixeira & Pais, 1973; P3rez Estaun, 1974).

The recovered assemblages of spores are assigned to the *Archaeoperisaccus ovalis-Verrucosiporites bulliferus* (OB) Biozone, of Frasnian age (Upper Devonian).

A detailed sampling through the Gimonde Formation in the Gimonde road and Quintanilha road sections yielded spores of the species *Aneurospora greggsii*, *Densosporites devonicus?*, *Geminospora lemuraia* and *Verrucosiporites scurrus*. Spores are very badly preserved but are assigned to the Givetian/Frasnian boundary.

The Rio de Onor road section provided a rich spore assemblage that includes *Aneurospora greggsii*, *Auroraspora* sp., *Archaeoperisaccus cf. ovalis*, *Contagisporites optivus*, *Hymenozonotriletes deliquescens*, *Lophozonotriletes* sp., *L. media*, *Retispora archaeolepidophyta*, *Samarisporites* sp., *Retusotriletes* sp., *Verrucosiporites bulliferus*, *V. scurrus*, *V. premnus* and *V. tumulentus* assigned to the *ovalis-bulliferus* Biozone of Frasnian age. The assemblage is complemented by Lower Devonian reworked spores, that include the species, *Brochotriletes* sp., *Dictyotriletes subgranifer*, *Emphanisporites microornatus*, *E. rotatus*, *Knoxisporites riondae*, *Retusotriletes* sp. and *Synorisporites verrucatus*, typical of Lochkovian and Praguian age. New investigations are been carried out in the sense of identifying the Lower Devonian in the lithostratigraphic sequence of the NE of Tr3s-os-Montes.

The palynomorph assemblages have proved to be an useful tool for precise dating of the Devonian formations in the Braganca region. These results allow the previous datings based on plants remains (Teixeira & Pais, 1973; P3rez Estaun, 1974) to be refined and prove to be very important for structural and geodynamic reconstructions.

Thus, spore assemblages recovered from the Gimonde Formation indicates an age close to the Givetian/Frasnian boundary. Further north in the Rio de Onor section, data from spores indicates a Frasnian age. Reworked spores of Lochkovian to Praguian age are also present in the assemblages.

**PRELIMINARY NOTE ON THE ORDOVICIAN-
SILURIAN STRATIGRAPHIC SEQUENCE OF THE
SERRA DE S3O MAMEDE REGION, SOUTHERN
BORDER OF THE CENTRAL IBERIAN ZONE,
PORTUGAL**

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The Serra de S3o Mamede, in the NE region of the Alentejo province, Portugal, defines a 30 km long topographic ridge situated at the southern border of the Central Iberian Zone (CIZ). Besides Ordovician granites occurring along its southern flank, the region is also known for the Palaeozoic siliciclastic sequence of which the Ordovician to Silurian component is here synthetically examined.

A revision of the regional geological map sheets in progress has allowed the identification of several composite stratigraphic sections in the northern and southern flanks of the S3o Mamede syncline and across the Alegrete-Esperanca ridge, which taken as a whole lead to the following preliminary conclusions:

1. The Ordovician is represented, from the bottom to the top, by: (a) the so-called Armorican Quartzite (quartzites with *Cruziana*), a succession of quartzites and interbedded conglomerate layers of Arenig age, whose thickness changes from 10 to 100 m; (b) a 100 m thick interval composed of shales and sandstones which yielded graptolites of Oretanian age; (c) a sandstone packet (10 m) followed by 20-30 m of dark grey shales; (d) a succession of bioturbated and lenticular sandstones of about 30 m in thickness, that resembles the Cabe3o do Pi3o Formation of the Am3ndoa-Ma3o Syncline (Young, 1990), of Caradoc age; (e) a thin bedded silty/shale suite, with some fine sandstone intercalations, of about 60 m in thickness, whose lower part shows spheroidal weathering affecting the shales, a lithological characteristic that is quite common in the Casal Carvalho Formation (Young, 1990) of late Ashgill age, that crops out in the Bu3aco, Domes and Am3ndoa-Ma3o synclines.

2. The Silurian comprises the following main units: (a) a 10-20 m thick unit of dark and pyrite-rich quartzites showing strong affinities with the Vale da Urso Formation (Cooper, 1980) of the Domes and Am3ndoa-Ma3o synclines; (b) a 30-40 m thick succession of black shales, locally micaceous and rich in fossiliferous nodules, lithologically similar to the Aboboreira Formation of the Ma3o-Am3ndoa syncline (Rom3o *et al.*, 1998), that provided graptolites from Llandovery to late Wenlock age; (c) a lithological sequence composed of unfossiliferous shales and siltstones, with a thickness in excess of 80 m, that becomes more rich in sandstone beds upwards; (d) the Silurian-Devonian boundary is not exactly known, being probably situated elsewhere in the upper sandstones which bear faunas (trilobites, brachiopods, etc.) of Lower Devonian age.

The Ordovician and Silurian sequences of the Serra de S3o Mamede region have many stratigraphic and sedimentological characteristics in common with those of several other regions situated at the southern border of the CIZ, both in Portugal (Valongo, Bu3aco, Domes, Am3ndoa-Ma3o) and Spain (Sierra de San Pedro, Soldevila, 1992; Almad3n, El Centenillo, etc., Guti3rrez-Marco *et al.*, 1998). This indicates that all these regions were part of the same major sedimentary basin, in this case a huge epicontinental sea (Oliveira *et al.*, 1992).

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**THE UPPER ALUCDIAN FROM THE
ALCUDIA ANTICLINE REVISITED
(CIUDAD REAL, CENTRAL SPAIN)**

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A very low-grade metasedimentary succession crops out forming the 120 km long pre-Ordovician core of the Alcudia river anticline in the south of the Central Iberian Zone. The presence of an angular unconformity was reported by a student of Prof. Lotze, Redlin (1955) separating what he considered a Lower Cambrian with limestones from an underlying turbiditic Precambrian sequence. These results were not following Lotze's ideas and thus the results were almost forgotten. An important mining evaluation project carried out in this anticline during the 70's rediscovered the unconformity and made popular the name Alcudian, which became a definitive reference for the correlations in the upper Proterozoic from the southern half of the Iberian Massif.

Later, the names Lower Alcudian and Upper Alcudian were used with a chronostratigraphic purpose, and they are found throughout the geological papers, but surprisingly, there is nothing like a formal definition of its units or a description of the sedimentology of the corresponding sequences. In addition to this, the late Precambrian age used by most of the recent authors is different from the age that can be deduced from recent palaeontological findings.

The lower unit (Lower Alcudian or Extremenian Dome Group), which base has never been found in the Central Iberian Zone, is Proterozoic (Riphean or Lower Vendian) and shows turbiditic characteristics. Above, the Upper Alcudian lies on an angular unconformity, locally with associated palaeoalteration. It is here subdivided into five lithostratigraphic units with range of Formation, which are from the base towards the top: (a) Tamujar Formation, formed by graywackes and arkoses; (b) Hinojosa Formation, with characteristic banded shales, graywackes, conglomerates and dolostone lenses, rich in trace fossils; (c) Lower shaley Formation formed mainly by shales; (d) the impressive conglomeratic San Lorenzo Formation; and (e) Upper shaley Formation where the shales predominate, but the base is formed by sandstones and graywackes, containing small shelly fossils.

The age of the Upper Alcudian, based on its trace fossil and microfossil content is Lower Cambrian (the basal four formations are Nemakit-Daldynian and the fifth formation is Tommotian). The Upper Alcudian is thus younger than the typical rocks from the Iber Group, and therefore the attribution to this unit should be abandoned. The name

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Alcudian was taken from this locality; so if we maintain it for local materials, the units forming the rest of the materials lying above the intra-Alcudian unconformity in the Central Iberian Zone, many of which are still Proterozoic (Upper Vendian), should be redefined or revised.

This also implies a revision of many of the correlations made by different research teams, which therefore may be no longer accurate. Thus, some of the correlations made for the Upper Alcudian by San José *et al.* (1990) and the presence of the sedimentary cycles described by these authors are no longer correct, because some were supposed to be much older than they are.

On the other hand, the correlation of all the uppermost Proterozoic platform facies, considered as an unique level, and the related existence of a basal unconformity between the Domo Extremenian Group (Lower Alcudian) and the Ibor Group (Upper Alcudian) as pointed by Álvarez-Nava *et al.* (1988), is not correct either, because the pre-Ordovician rocks from the Ibor anticline are older (Upper Vendian) than those from Alcudia anticline (Cambrian). Therefore both ensembles cannot be included together within the Ibor Group.

LATE PROTEROZOIC CRUSTAL GROWTH IN OSSA-MORENA: Nd ISOTOPE AND TRACE ELEMENT EVIDENCE FROM THE SIERRA DE CÓRDOBA VOLCANICS

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Several calc-alkaline volcanic rocks from the Precambrian basement of the Ossa-Morena Zone (San Jerónimo Formation) have been analysed for the Sm-Nd isotopic system and REE, Rb, Sr, Zr, Nb and Ni content. These rocks are generally porphyritic to microporphyritic andesites, with abundant plagioclase (\pm amphibole) phenocrysts. With the exception of two samples, they display positive ϵ_{Nd} values, ranging from +2.9 to +7.4. Most of them, with +4 < ϵ_{Nd} < +6, exhibit LREE enrichment ($La_N/Lu_N=2.3-4.9$), strong negative Nb anomalies and Zr/Nb ratios range from 21 to 32. There is no obvious correlation between the shape of REE patterns, La/Nb ratios and ϵ_{Nd} values, precluding simple models of late-stage interaction with typical crustal components with low ϵ_{Nd} and large LREE/HREE and La/Nb ratios.

Based on their enriched, crustal trace element characteristics, combined with distinctly positive ϵ_{Nd} values, the Sierra de Córdoba andesites are interpreted to document an episode of crustal growth through addition of calc-alkaline magma, extracted from a depleted mantle reservoir. The occurrence of subordinate amounts of rocks with negative ϵ_{Nd} values does not favour a purely ensimatic arc setting for this subduction-related magmatism, although assimilation of sediments during magma fractionation might also account for the isotopic data. Overall, these suggest that an active continental margin environment, involving concomitant crustal growth, prevailed in the latest Proterozoic of southern Iberia.

350 Ma (U-Pb ZIRCON) IGNEOUS EMPLACEMENT AGE AND Sr-Nd ISOTOPIC STUDY OF THE BEJA GABBROIC COMPLEX (S. PORTUGAL)

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The boundary between the highly contrasting Ossa-Morena and South Portuguese Zones of the Iberian Variscan orogen is interpreted as a major suture zone (Andrade, 1977). In

Spain and Portugal, this is represented by discontinuous strips of mafic rocks with broadly oceanic geochemical affinities, regarded to represent an extremely disrupted ophiolite (the so-called Beja-Acebuches Ophiolitic Complex; Munhá *et al.*, 1986, 1989), and by mélange deposits of Middle to Late Devonian age (Eden & Andrew, 1990, 1991) in the Pulo do Lobo Accretionary Terrane (Quesada *et al.*, 1994, and references therein). Based on the palaeontologically documented age of the overlying Horta da Torre Formation, the ophiolite/mélange emplacement occurred earlier than the Famennian (Oliveira *et al.*, 1986). After accretion-related deformation in a thrust regime, tentatively interpreted in terms of north-eastward obduction (Fonseca & Ribeiro, 1993), the suture zone was affected by SW-directed thrusting evolving to left-lateral ductile shearing movements (Crespo-Blanc & Orozco, 1988; Quesada *et al.*, 1994), interpreted as a result of oblique collision between the South Portuguese Terrane and the Iberian Autochthon.

The large Beja gabbroic complex was interpreted either as part of the ophiolite-like units (e.g. Andrade *et al.*, 1976; Andrade, 1977), or as a broadly arc-related massif reflecting the northward subduction of oceanic crust (Quesada *et al.*, 1994). Although the gabbroic complex is locally deformed, it rather appears as a stitching pluton, intruded into the previously accreted ophiolite-like unit and the continental rocks of the Ossa-Morena Zone, possibly during the left-lateral transpressional deformation (Dallmeyer *et al.*, 1993; Quesada *et al.*, 1994). Available radiometric data in this area are limited to ³⁹Ar/⁴⁰Ar measurements on amphibole, which indicate that cooling below the ca. 500°C isotherm occurred about 340 Ma ago in that area (Dallmeyer *et al.*, 1993). However, Ruffet (1990) interpreted a 336.4±0.8 Ma plateau age of an amphibole from the Beja gabbro in terms of an unrealistically high closure temperature around 800°C, while Dallmeyer *et al.* (1993) considered as likely that their 339±1 Ma ages on hornblende were not significantly younger than crystallization of the pluton.

In order to put tighter constraints on the igneous emplacement age of the Beja gabbroic complex, two samples were collected in the eastern (Serpa) and western (Torrao) parts of the massif, and studied by the U-Pb dating method on zircon concentrates. Nearly concordant data points were obtained in both cases, corresponding to ages of 350±4 Ma (2 σ) at Serpa and 352±4 Ma at Torrao that we interpret in terms of igneous emplacement, based on the >900°C blocking temperature of the U-Pb system in zircons (Lee *et al.*, 1997).

These results clearly demonstrate that the Ar/Ar dates obtained on the Beja gabbro (Ruffet, 1990; Dallmeyer *et al.*, 1993) do not represent igneous crystallization ages. Ar/Ar ages measured on amphiboles from the country-rocks of the gabbro, both in the ophiolite-like units and in the Ossa-Morena Zone (Dallmeyer *et al.*, 1993) also cluster around 340 Ma. It is concluded that the Ar/Ar ages merely reflect the regional cooling below 500°C, which occurred at least 10 Ma after the magmatic emplacement of the Beja gabbro, and probably records the uplift of the suture zone relative to the subsiding South Portuguese Zone.

It is also clear that the 350 Ma igneous age invalidates the palaeomagnetic reconstructions proposed by Perroud *et al.* (1985), which were based on results obtained on the Beja gabbro, assumed to be Late Devonian. As a corollary, the large oceanic domain (about 1,700 km) inferred by these authors between southern and northern Iberia should be dismissed, with significant implications on the timing of final accretion of the Variscan Belt in that area.

Based on available geological timescales, the ca. 350 Ma age corresponds to the Late Tournaisian, suggesting that the intrusion of the Beja gabbro occurred at the same time as the volcanic activity recorded in the Toca da Moura complex in the Santa Susana region (Santos *et al.*, 1987), about 20 km to the NW. At a larger scale, the Beja gabbro is also broadly coeval with the bimodal volcanism of the Pyrite Belt in the South Portuguese Zone (Schermmerhorn, 1970; Munhá, 1979), and, more tentatively, with mafic-ultramafic occurrences scattered along a NW-SE lineament south of the Los Pedroches batholith (Crousilles *et al.*, 1976). Taking into account this large scale context, it may be inferred that the magmatic emplacement of the Beja gabbro occurred in an extensional (probably, transtensional) tectonic setting, much more favourable than a compressional one to the ascent and emplacement into the crust of a large, mantle-derived magma body. Also, the Beja gabbro was not related to an active subduction of oceanic lithosphere, in view of the probable pre-Famennian age of the collision between the Ossa-Morena and South

Portuguese Zones (Oliveira *et al.*, 1986; Munhá *et al.*, 1989). Its internal deformation probably occurred during the Late Viséan to Middle Westphalian compressional episodes well documented in the Pyrite Belt by SW-propagating thin-skinned fold and nappe tectonics and synorogenic flysch sedimentation (Oliveira, 1990; Silva *et al.*, 1990; Quesada, 1997).

20 samples of the Beja gabbroic complex have been analysed for the Rb-Sr and 12 for the Sm-Nd isotope systematics, using isotope dilution thermal ionization mass spectrometry. The measured Sr and Nd isotopic results have been corrected for *in situ* radioactive decay of ⁸⁷Rb and ¹⁴⁷Sm using the 350 Ma U-Pb zircon age. No isochron relationship was obtained. However, four samples collected at Torrao enable an errorchron (MSWD=5.6) to be calculated, corresponding to an age of 351±31 Ma (2 σ) in good agreement with the U-Pb zircon age. The age-corrected ⁸⁷Sr/⁸⁶Sr₃₅₀ and $\epsilon_{Nd_{350}}$ display a large range of values (from 0.7041 to 0.7093 and from +4.0 to -6.1, respectively) which documents a rather complex petrogenetic history. The more primitive Sr and Nd isotope signatures are measured in the mafic cumulates south of Odivelas, while radiogenic Sr and unradiogenic Nd isotope compositions occur in the more evolved facies exposed near Serpa. The trend of decreasing $\epsilon_{Nd_{350}}$ with decreasing ¹⁴⁷Sm/¹⁴⁴Nd and increasing SiO₂ concentration is reminiscent of crustal assimilation combined with fractional assimilation (AFC). A peculiar sample collected near Serpa has a continental crust-like signature (⁸⁷Sr/⁸⁶Sr₃₅₀=0.719 and $\epsilon_{Nd_{350}}=-9.3$) suggesting that very large degrees of contamination occurred close to the margin of the plutonic body.

Preliminary data obtained on samples from the ophiolite-like unit in the Guadiana valley show that the faser-gabbros display ϵ_{Nd} values close to zero or even slightly negative, irrespective of the age chosen for the correction for *in situ* radioactive decay of ¹⁴⁷Sm in the range 350-500 Ma, assumed to encompass the true geological age. This is because the ¹⁴⁷Sm/¹⁴⁴Nd ratio of these rocks does not differ greatly from the chondritic value, making the calculation of ϵ_{Nd} relatively insensitive to the age correction. In contrast, most amphibolites (metabasalts) of the same area, sampled north and south of the Beja gabbro, have positive, albeit variable ϵ_{Nd} . Only a few samples reach highly positive values ($\epsilon_{Nd_{350 \text{ or } 500} \text{ ca. } +8}$) similar to those typical for N-MORBs. These samples resemble the Acebuches amphibolites (Bard, 1977; Dupuy *et al.*, 1979; Quesada *et al.*, 1994). Four samples of these amphibolites, collected south of Aracena, give fairly homogeneous ϵ_{Nd} values ca. +9, irrespective of the age (350 Ma or 500 Ma) assumed for the correction of *in situ* radioactive decay, as also shown by Castro *et al.* (1996). These isotopic results suggest that the Beja-Acebuches ophiolitic complex is not only disrupted and geochemically heterogeneous (Quesada *et al.*, 1994), but also composite, since the gabbroic rocks do not appear to be co-genetic with the metabasalts. Based on Nd isotope evidence, it is suggested that only some of the metabasalts were extracted from a mantle source that was highly depleted in LREE on a time-integrated basis and did not suffer significant interaction with continental components. Only these metabasalts display unequivocal, N-MORB-like oceanic affinities, as do the igneous blocks from the Peramora Melange of the Pulo do Lobo Formation, as inferred from their REE characteristics (Eden, 1991).

BAIKALIAN/CADOMIAN DEFORMATION AND METAMORPHISM ALONG THE NORTHERN MARGIN OF BALTICA, NW RUSSIA AND NE NORWAY

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Neoproterozoic lithostratigraphic successions metamorphosed at low to very low-grade characterise the northern extremity of Baltica adjacent to the Barents and Pechora Seas. Extending over some 1,800 km from the Timan range and Kanin Peninsula in NW Russia, via the Rybachi and Sredni Peninsulas of Kola to the northeastern part of Vanger Peninsula in Norway, these predominantly terrigenous successions were deposited in two different sedimentation regimes or domains (pericratonic and basinal) separated by a major fault zone trending NW-SE. Marked contrasts in both thicknesses and sedimentary facies are found between the fluvial to locally shallow-marine, pericratonic successions to the southwest of the fault zone, and the largely marine, in part turbiditic rocks of the basinal regime; and island-arc volcanics of higher metamorphic grade, cut by granites, occur beneath the Pechora Basin