

**ABSTRACTS OF PRESENTATIONS RELATED TO
IGCP 458 (TRIASSIC-JURASSIC BOUNDARY EVENTS)**

**HETTANGIAN AMMONITES AND RADIOLARIANS IN THE MT.
CAMICIA SUCCESSION (GRAN SASSO, CENTRAL APENNINES)**

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The Gran Sasso range contains two different Late Triassic - Early Liassic facies: a) shallow-water carbonate facies in the western part (Corno Grande), with the Dolomia Principale Fm. in the Late Triassic and the Calcare Massiccio Fm. in the Early Liassic; b) euxinic to open-pelagic facies on the eastern part (Mt. Camicia). Adamoli *et al.* (1990) described the following lithologic intervals in the lower part of the Mt. Camicia succession (Vradda section): 1) thin-bedded bituminous dolostones (Scisti Bituminosi Auctt.), referred to the Late Triassic; 2) thin-bedded dolostones (Vradda Dolostones); 3) mottled limestones in thickening upward cycles with thin bedded micrite and calcarenites (Spotted Limestone); 4) Ammonitic Beds referred to the Early Liassic p.p.; 5) Corniola Fm. with cherty micrites, calcarenites and calcirudites (Early Liassic p.p. - Middle Liassic); it is followed by the Late Liassic "Verde Ammonitico" Fm.

The Ammonitic Beds (20 m. thick) crop out on the eastern side of the "Vallone di Vradda" and they have been studied along various stratigraphic sections. The Ammonitic Beds are made of thin-bedded micrites and calcarenites and they are quite similar to the overlying Corniola; the calcarenites in the upper part of the section are sometimes silicified. An anoxic level (4-5 cm thick), made of a felted bituminous matter, is present in the lower part.

Six thin levels with abundant small-sized ammonites were found in the calcarenites: a) the lower level contains abundant specimens of "*Euphyllites*" n. sp. indet. and rare specimens of n. gen. indet. aff. *Discamphiceras* (Middle Hettangian ?); b) the second level contains a minor amount of specimens: "*Euphyllites*", *Wähneroceras* sp. indet., *Schlotheimia* sp. indet. and a gen. indet. (Pseudotropitinae) (Late Hettangian); c-d) the third and fourth levels contain many specimens of "*Analytoceras*" n. sp. indet., rare specimens of *Schlotheimia* sp. indet., a gen. indet. aff. *Discamphiceras* and *Pseudaetomoceras doetzkirchneri* (Late Hettangian); e) the fifth contains rare specimens of *Paracaloceras* sp. indet. and *Sunrisites* sp. indet. (Late Hettangian); f) the sixth contains many specimens of *Gyrophioceras praespiratissimus* and *G. supraspiratum* Wähner, and rare specimens of *Schlotheimia* sp. indet. (Late Hettangian). The largest part of these taxa are completely unknown in Italy; this assemblage shows some analogies with the Adnet fauna (Northern Calcareous Alps) (Wähner, 1882-97).

The Ammonitic Beds of Mt. Camicia are very rich in radiolarians which are often calcitized; just in the lower (a) and in the upper (f) levels we have found many well preserved specimens. These are characterized by spherical and irregularly spinose forms, often with tubercles. The most abundant genus is *Praeconocaryomma*. The first occurrence of this genus was reported from the Early Sinemurian (Yeh & Cheng, 1998); the ammonites found in the Vradda section suggest that this genus was present since at least the Middle Hettangian. Studies on the other specimens found in the first and in the sixth levels are in progress.

The results of this research are: a) a further support for the existence of a pelagic basin in the eastern part of the Gran Sasso range since at least the Early Liassic; b) a first documentation of a succession of Hettangian ammonites in Italy; c) a correlation of some radiolarian taxa with the ammonites biozones.

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PSILO CERATIDS OF THE EARLIEST JURASSIC IN THE NORTH- WEST EUROPEAN AND MEDITERRANEAN PROVINCES – A COMPARISON

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In recent years it has become well established that the smooth-shelled psiloceratids of the basal Jurassic Planorbis Subzone do not represent a single faunal assemblage, as formerly believed, but occur in successions of different species, most notably in the NW European Province (Bloos and Page, 2000) and in South America (Hillebrandt, 2000). In other faunal provinces (e.g. in the Mediterranean Province as best represented in the NE Alps, and in North America, best in Nevada) this differentiation appears less marked. Faunal endemism renders exact correlations between these regions difficult.

The present paper concentrates on the relationship between the faunas of the NW European and the Mediterranean provinces. In the former province, despite only the higher parts of the Planorbis Subzone faunal succession being widespread, a very complete succession is known from the Wilkesley Borehole, NW England (Bloos and Page, 2000), comprising, in sequence: *Psiloceras erugatum*, *Neophyllites imitans*, *N. antecedens*, *P. planorbis*, *P. psilonotum*, *P. psilonotum/P. plicatulum*. Characteristic of all these psiloceratids is a simple suture line with shallow indentations of the saddles and mostly without indentations of second order. Virtually all of these forms have macroconchs with essentially smooth inner whorls, excepting *P. erugatum* which exhibits well developed nodes and some ribbing on the innermost whorls. The body chamber is about one whorl. Microconchs are only well characterised in the *psilonotum* assemblage, as “*P. brevicellatum*” (Quenstedt) and resemble perfectly to the inner whorls of the former species. They are small forms with trumpet-like apertures, immediately preceded by a constriction. The body chamber is short, only half a whorl in contrast to that of the macroconch.

The characteristic basal species in the NE Alps is *P. calliphyllum*. For a long time, *P. psilonotum* was regarded as a NW European ecological variant of the former, but there are considerable differences between the two groups. In *P. calliphyllum*, not only is the suture line more differentiated, but there are also well developed nodes and distinct ribs on the innermost whorls, in contrast to *P. psilonotum*. In addition, the flanks of *P. calliphyllum* are more flat than in *P. psilonotum*. An unnamed microconch form which corresponds well with macroconch *P. calliphyllum* always co-occurs.

Also associated with *P. calliphyllum* are numerous more or less ribbed microconch forms. These are *Waehneroceras* s. str. of which the type species *W. tenerum* is the best known. These *Waehneroceras* are conspicuously different from the NW European forms assigned to *Curviceras*. *Curviceras* appears in NW Europe at the base of the Liasicus Zone and in the Alps in the Megastoma Zone, thereby postdating *Waehneroceras* s. str. The corresponding macroconchs of *Waehneroceras* s. str. are not yet known. *Waehneroceras* s. str., though older than *Curviceras*, is certainly post basal Jurassic and consequently so is *P. calliphyllum*.

The collections of the Museum of Natural History in Vienna includes more than 20 specimens of typical *Neophyllites* and two related to *P. psilonotum* from the famous locality of Fonsjoch. The exact stratigraphic position of these specimens in relation to *P. calliphyllum* is not yet known, but they may indicate that the alpine psiloceratids known at present are not older than their NW European counterparts.

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GEOCHEMICAL EVIDENCE FOR THE CAUSE OF ENVIRONMENTAL CHANGE AT THE TRIASSIC–JURASSIC BOUNDARY

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The late Triassic–early Jurassic was a time of major global change. This interval marks one of the “big five” extinction events of the Phanerozoic; there is also clear evidence for a marked rise in eustatic sea-level and for widespread igneous activity in the Central Atlantic magmatic province. Both the sedimentary and palaeontological records suggest that the environmental changes associated with the Tr–J boundary occurred relatively quickly. Few causal mechanisms are able to produce such severe and lasting effects. These include meteorite impacts, the sudden onset of extensive volcanism and the reorganization of tectonic plates. We discuss new geochemical data that (1) reveal a highly plausible cause for the environmental changes and (2) directly link the initiation of this cause to the marine stratigraphical record.

We have determined the Re and Os abundances, and Os isotope compositions, of marine mudrocks that span the Triassic–Jurassic boundary at St. Audrie’s Bay (proposed Tr–J boundary GSSP), Watchet Harbour, and Lavernock Point, in the UK and have established that major isotopic and geochemical shifts in the composition of seawater took place in the latest Triassic (Cohen & Coe 2002). These shifts can most easily be explained by the sudden initiation of widespread igneous activity within the Central Atlantic magmatic province, associated with rifting of the supercontinent Pangea. The Os isotope composition of seawater responded rapidly to these events, demonstrating that the seawater Os isotope system has great potential in identifying the nature and precise timing of major environmental change.

The Os abundance increases in the pre-planorbis beds (Rhaetian) at *c.*3m below the first appearance of the ammonite genus *Psiloceras*, and is closely followed by a pronounced increase in Re abundance *c.*1m above the boundary. This lag period may reflect the more rapid buildup of Os in seawater that is expected from the difference in their present-day seawater residence times. Calculated $^{187}\text{Os}/^{188}\text{Os}_{(i)}$ ratios change from high values in samples in the Westbury Formation (Rhaetian) to lower values in samples from the Lias Group (Hettangian).

The increase in Os abundance corresponds almost exactly with the onset of a long-term positive carbon-isotope shift reported from the St Audries Bay section by Hesselbo *et al.* (2002), which the authors independently interpreted to be due to substantial volcanic activity associated with the Central Atlantic magmatic province.

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THE SOUTHERN ALPS: A KEY AREA FOR A COMPLETE CARBON ISOTOPIC STRATIGRAPHY ACROSS THE TRIASSIC/JURASSIC BOUNDARY

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The latest Triassic was a period of intense biological change that culminated in one of the five largest and most enigmatic mass extinction events (Tanner *et al.*, 2001) of the Phanerozoic. A clear assessment of the Late-Triassic mass extinction has been hindered by the scarce number of continuous marine sections spanning the Triassic/Jurassic boundary. In the western Southern Alps, the Bergamasc Alps provide an excellent opportunity to study the latest Triassic-earliest Jurassic sequence without stratigraphic gaps or hiatuses. An integrated approach has been used to characterize the stratigraphic and paleo-environmental setting of this area across the Triassic/Jurassic boundary, applying palynological, lithological and stable isotope techniques. This study offers the opportunity to test models proposing major C-cycle perturbations as the cause of the extinction event.

In the Western Southern Alps, the Rhaetian-Hettangian is represented by four shallowing-upward, third-order-tectono-eustatic sequences. The two Rhaetian sequences are well organized into several, decameter to meter scale, shale-carbonate parasequences that document the regional evolution, from a distal to a proximal depositional environment of an articulated homoclinal carbonate ramp (Zu Limestone, Lakew, 1990; Jadoul *et al.*, 1994). The Hettangian ooidal and peloidal “Bahamian” carbonate platform deposits (Conchodon Dolomite) developed following a regional transgression indicated by the presence of thin-bedded, dark grey subtidal micritic limestones (uppermost Zu Limestones, Jadoul *et al.*, 1994). Palynological studies conducted on numerous sections have enabled the location of the T/J boundary in the micritic limestones of uppermost Zu Limestone. The boundary is identifiable in the same stratigraphic position and facilitated the correlation between the sections. Within this sequence-stratigraphic setting, the T/J boundary in the Bergamasc Alps corresponds to the maximum flooding of the first Hettangian sequence (Cirilli *et al.*, 2001).

Here we present detailed records from two of the most well-exposed sites, the Albenza and the Iseo sections. The carbon isotopic signal, based on the analysis of bulk carbonate samples, is used as a proxy for stratigraphic correlation and for paleo-environmental interpretation. Data show a 2‰ positive excursion with a maximum value of +4‰ at the close of the Triassic. A 2‰ negative shift in C-isotope values occurs just after the Triassic/Jurassic boundary. Major disappearance of marine organisms (Lakew, 1990; Borsato *et al.*, 1994) starts before the Triassic/Jurassic boundary and coincides with the base of the positive C-isotope anomaly, possibly recording a perturbation of the global C-cycle across the Triassic/Jurassic boundary.

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TRIASSIC-JURASSIC BOUNDARY STRATA, QUEEN CHARLOTTE ISLANDS, BRITISH COLUMBIA, CANADA

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Continuous stratigraphic sections spanning the Triassic/Jurassic boundary are known at two localities on Queen Charlotte Islands, Canada. Exposures at Kunga Island and Kennecott Point contain conformable successions ranging from Upper Norian to Middle/Upper Hettangian and Upper Norian to Lower Sinemurian, respectively. We have initiated a multidisciplinary study to characterize these strata as completely as possible, so that they can be considered as possible GSSP candidate sections.

The succession at Kunga Island consists of a homogeneous succession of siliceous siltstone with minor interbeds of fine- to medium-grained sandstone, all assigned to the Sandilands Formation (Kunga Group). Fine-grained strata appear massive with few internal fabrics discernible. Calcareous nodules, containing microfossils, are common in finer grained facies. At Kennecott Point, boundary strata are also assigned to the Sandilands Formation; these rocks consist of silicified, organic-rich, laminated to massive black shale, alternating with siltstone to medium-grained sandstone. Sedimentary structures include low-angle planar cross-stratification, flame structures, hummocky cross-stratification, and graded bedding. Trace fossils are rare in fine-grained facies, more common in coarse-grained facies, and include both grazing and burrowing types. Thin (0.25-2.0 cm), gray to buff tuff beds are present in both sections, but more commonly at Kennecott Point.

Many beds in the Sandilands Formation show features of turbidite deposition, and the formation has thus been previously considered as a deep-basin deposit. We suggest, however, that some of the coarser interbeds in the upper part of the formation at Kennecott Point are distal storm deposits. The presence of abundant laminated black shale in the section suggests anoxic bottom conditions, which may account for the lack of benthic fauna within these beds. We believe that the boundary between oxic and anoxic bottom conditions was limited to a few decimetres or less, to allow colonization by grazers and infauna during times of coarser sediment influx, perhaps following storm events.

A dramatic turnover of radiolarian taxa defines the Triassic/Jurassic boundary at both localities. Radiolarians place the system boundary within a 1m-thick interval at Kunga Island and a 10 m-thick interval at Kennecott Point; the presence of *Choristoceras* spp. in the latter section further refines the boundary interval to approximately 5.5 m stratigraphic thickness.

Trends in $\delta^{13}C$ organic carbon in the Kunga Island section indicate the isotopic signal has been degraded, possibly due to diagenesis. Isotopic data from Kennecott Point show a pronounced negative perturbation in $\delta^{13}C$ organic carbon, suggesting a dramatic decline in global organic productivity (Ward et al., 2001). This negative excursion is found at the precise level of the palaeontologically-defined extinction event and is estimated to have taken place over 50,000 years or less, suggesting very rapid environmental change.

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NEW HETTANGIAN AMMONITE FAUNAS AND THE TRIASSIC - JURASSIC BOUNDARY, FERNIE FORMATION, WILLISTON LAKE, BRITISH COLUMBIA

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Three shoreline sections on Peace Reach, Williston Lake, north-eastern British Columbia provide continuous exposures across the Triassic/Jurassic boundary interval, passing with apparent stratigraphic continuity from the Pardonet Formation into the overlying Fernie Formation. A fourth section near Crying Girl Prairie, 45 km north of these lakeshore sections, also exposes this boundary interval. These rock sequences are part of autochthonous North America, deposited along the western margin of the Jurassic craton.

The section at Black Bear Ridge consists of 22m of flaggy-bedded, brown-weathering siltstones and several thick, resistant siltstones, and contains calcareous concretions which have yielded most of the three-dimensional ammonites. While it is clear these ammonites represent parts of the lower, middle and upper Hettangian, the sequence of faunas differs somewhat from sequences reported from the Queen Charlotte Islands and in Nevada.

Overlying the sudden disappearance of abundant *Monotis subcircularis* (near the top of the Triassic Pardonet Formation, and used here as a datum) are five metres of siltstones which are only sparsely fossiliferous, having yielded several specimens of *Monotis* at 1.0 – 1.3m, fragments of the conodont *Epigondolella* from two thin, calcareous beds at 1.4 and 1.6m, and poorly preserved psiloceratid ammonites at 2.5 and 4.05m.

Lower Hettangian faunas include poorly preserved, laterally flattened *Psiloceras* (*P. plicatulum*, *P. plicatum*, *P. rectocostatum*), occurring throughout the lower 8.6m of section. At 9.5m in the section, *Curviceras subangulare* and *Waehneroceras* appear, representing the middle Hettangian, with *Caloceras crassicostatum* and the first *Schlotheimia* appearing a little higher. A single large specimen of *Alsatites liasicus* is associated with these faunas. Beds above 13.3m yield several species of *Schlotheimia* (*S. angulata*, *S. angulata densicostata*, *S. eugemethes*), *Kammerkarites frigga* and *Sunrisites*, indicating the lower parts of the upper Hettangian. Uppermost Hettangian faunas occur at the top of the exposed section in beds from 19.5 to 21.7m, and include *Badouxia* (*B. canadensis*, *B. striata*, *B. oregonensis*) and *Pseudaetomoceras doetzkirchneri*. This is the first record of an extensive sequence of Hettangian strata and ammonite faunas in the Fernie Formation; basal Fernie strata at most localities consist of a Sinemurian pebble lag, or Pliensbachian platy, black limestones, or Lower Toarcian black, papery shales.

At Crying Girl Prairie, laterally crushed specimens of *Psiloceras polymorphum* are numerous in a series of four beds between 1.0 and 1.6m above a pebble lag which marks the top of the *Monotis* beds at this locality. A further 18m upsection, above unfossiliferous, black, poorly-bedded siltstones, flattened lateral impressions of ?*Alsatites* were collected.

PRECISE CORRELATION OF RADIOLARIA AT THE TRIASSIC/JURASSIC BOUNDARY BETWEEN INUYAMA, JAPAN AND QUEEN CHARLOTTE ISLANDS, WESTERN NORTH AMERICA

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We have carried out a precise comparison of the radiolarian fauna from the Inuyama area, southwest Japan and from two localities in Queen Charlotte Islands, British Columbia to clarify faunal change across the Triassic/Jurassic (T/J) system boundary. The Inuyama area is representative of deep-sea sediments deposited below CCD depth whereas Queen Charlotte Island localities represent an outer shelf to upper slope setting (Haggart *et al.* 2001) where co-occurring ammonites and conodonts are also found. Rock thickness varies greatly between the two areas: in Inuyama the Rhaetian-Hettangian condensed chert sequence is ~4m thick; clastic sequences of equivalent age in Queen Charlotte Islands are over 130m thick.

Despite the great variation in thickness in both areas, we recognize similar changes in the radiolarian fauna. These changes occur stepwise as follows: 1) rapid decrease in the diverse Rhaetian (Upper Triassic) radiolarian fauna with many species apparently going extinct; 2) first appearance of primitive radiolarians (Hettangian) occurring simultaneously with remnants of the Rhaetian fauna; 3) high content of spherical spumellaria coinciding with the second event. During the first event, the abundance of genera such as *Canoptum*, *Deflandrecyrtium*, *Haeckelicyrtium*, *Livarella*, and *Risella* decreases remarkably and many species abruptly disappear. At the second level, *Deflandrecyrtium* sp. A of Carter (1993), *Livarella validus* and *Pentaspongodiscus? dihexacanthus* make their final appearance in both Inuyama and Queen Charlotte Islands. At this same level in Japan, *Pantanellium tanuense*, *Palaeosaturnalis tetraradiatus* and primitive forms of Jurassic-type *Bipedis* first appear and are representative of the lowest Jurassic. In Queen Charlotte Islands, the first appearance of lowest Hettangian species generally does not coincide with the final appearance of uppermost Rhaetian species, but takes place slightly higher in the sequence (2.4m). However, at one new locality distinctive but comparatively rare Rhaetian species co-occur with a much more abundant lower Hettangian fauna. The third event is characterized by the high abundance of spherical spumellarians such as *Archaeocenosphaera laseekensis* and Spumellaria indet A of Carter *et al.* (1998) and associated diagnostic Hettangian species.

The duration from the first to second event levels is estimated at less than 1myr, perhaps on the order of 0.5myr, which is consistent with the negative excursion of carbon isotopes observed at Kennecott Point, Queen Charlotte Islands (Ward *et al.* 2001). This may similarly represent the interval between productivity collapse at the end of the Triassic and the resumption of primary productivity in the Lower Jurassic.

RADIOLARIAN FAUNAS AROUND THE TRIASSIC/JURASSIC BOUNDARY IN CHERT SEQUENCES IN BUSUANGA ISLAND, NORTH PALAWAN BLOCK (PHILIPPINES)

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Busuanga Island is considered an accretionary complexes primarily composed of Middle Permian to Jurassic chert (Liminangcong Formation), Middle Jurassic to Early Cretaceous clastics (Guinlo Formation) and limestone units of various ages, with minor melange bodies, collectively called as the Malampaya Sound Group (Hashimoto and Sato, 1973; Zamoras and Matsuoka, 2001). These rocks are interpreted as offscraped sedimentary sequences from a subducted oceanic plate that developed an imbricate structure during the Jurassic-Cretaceous accretion.

Deep-sea pelagic sediments of Triassic and Jurassic age are represented by chert sequences and contain many radiolarian tests. The Upper Triassic to Lower Jurassic continuous sections are recognized in several localities in Busuanga Island. The Dipuyay section located west of Dipuyay crops out along a road and is exposed approximately 1.5 km long. We carried out radiolarian biostratigraphic studies along this section. Radiolarian faunas of Early Jurassic age have already been reported from this section by Tumanda (1991) and Yeh and Cheng (1998).

The Dipuyay section is composed mainly of bedded chert associated with massive chert. The chert exhibits a wide range of color variation such as red, maroon, flesh, green and gray. Its prevalent folded and occasionally faulted structures combined with its generally road-parallel strike of the bedding planes cause certain difficulty in determining or understanding its lithostratigraphy and biostratigraphy. The alternating occurrences of Late Triassic and Early Jurassic radiolarian assemblages along the section are due partly to section-parallel nature of the bedding planes and partly to tectonic repetitions. We found at least three candidates of the Triassic/Jurassic boundary.

The most common species in Jurassic chert are *Bipedis patricki*, *Katroma irvingi*, and *Pleesus* sp. aff. *P. aptus* and *Parahsuum* sp. Other radiolarians include *Charlottea triquetta*, *Sophia tubaris* and *Pantanellium skedansense*. Most of these radiolarians appear in the Hettangian and Sinemurian strata in the Queen Charlotte Islands, Canada. The assemblage is assignable to JR0 of the Japan-Pacific radiolarian zonal scheme.

Regarding Triassic assemblages research is in progress. A certain sample contains *Praemesosaturnalis sandspitensis* and *Kozurastrum* spp., indicative of Late Triassic age. Another sample yields *Livarella* sp. of Triassic affinity.

ADVANCES IN THE INTEGRATED STRATIGRAPHY OF THE JURASSIC

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In recent years, significant progress has been made in using diverse approaches to stratigraphic problems in the Jurassic. Historically, Jurassic studies were in the forefront of developing fundamental concepts and the first zonal schemes in biostratigraphy. Now, as the emphasis shifts towards other stratigraphic methods and their integration, the Jurassic continues to be the subject of much modern research, the highlights of which are reviewed here.

The basic Jurassic chronostratigraphic framework is being formally defined by a growing number of GSSPs: after the Bajocian, now the base of Aalenian and Sinemurian stages is also agreed upon, the Pliensbachian is soon to follow, and others are also in progress. By virtue of the requirements for a GSSP, settling these boundary issues invariably resulted in producing large quantities of broad and integrated stratigraphic data.

In biostratigraphy, high-resolution studies, integration of zonation of different fossil groups, and developing regional standards for previously less studied areas remain the priority research areas.

A suite of new radiometric dates was obtained recently, resulting in a revision of the Jurassic numeric time scale. Of significance are the improved date of the Triassic–Jurassic boundary, an independent set of dates on demonstrably coeval basalts of the Central Atlantic Magmatic Province, and a zonally resolved portion of the time scale in the Late Pliensbachian–Early Toarcian. The Early Jurassic part of the time scale is much better calibrated than the Late Jurassic, which clearly needs more isotopic ages as tie-points.

Several studies focused on the magnetostratigraphy of the Triassic–Jurassic transition from different parts of the world, documenting an extended normal polarity chron across the system boundary.

Cyclostratigraphy of sediments responding to astronomical forcing allows independent estimation of time. The coverage of floating Milankovitch time scales is increasing throughout the Jurassic: new data have been generated or compiled for the Hettangian, Pliensbachian, Toarcian, Aalenian, and Kimmeridgian.

Carbon isotope stratigraphy enjoys growing popularity as both a proxy of environmental change and a correlation tool. Significant negative anomalies were recently recognized from several localities at the Triassic–Jurassic boundary and in the early Toarcian, supplemented by reports from the Bajocian and the Oxfordian. More data became available to document the positive excursions in the Early Toarcian and the Kimmeridgian. Some of the short-lived negative spikes were suggested to be related to release of methane from sedimentary gas-hydrate reservoirs at times of rapid climate warming. The anomaly at the Triassic–Jurassic boundary may be particularly useful for worldwide and marine-to-terrestrial correlation.

High-resolution Early Jurassic strontium isotope stratigraphic studies highlighted the correlation potential of this tool and spawned a novel interpolation method for time scale calibration, based on the assumption of linear change in the seawater $^{87}\text{Sr}/^{86}\text{Sr}$ ratio through limited intervals.

There are ample examples how an integrated approach to stratigraphy enhanced correlation of different types of Jurassic rocks, and geological and biological events. Refinements in the time scale allowed better estimation of rates of various Earth processes which, together with improved correlation, also helped gain new insights about the driving forces and relationships of environmental and biotic changes, and geological events in the Jurassic.

THE TRIASSIC/JURASSIC BOUNDARY IN THE ANDES OF ARGENTINA

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The Arroyo Malo Formation at Alumbre creek, on the northern bank of the Atuel river, west central Argentina, comprises a c. 300 m thick, continuous marine succession across the Triassic-Jurassic System boundary, consisting of massive and laminated pelites indicative of a slope depositional environment. Late Triassic invertebrates, including ammonoids, nautiloids, bivalves, gastropods, brachiopods and corals, are restricted to the lower 150 m (Riccardi *et al.* 1997a-b, Damborenea & Manceñido 1998, Riccardi & Iglesia Llanos 1999). Beds between 125-135 m from the bottom yield *Choristoceras* cf. *C. marshi* Hauer, a species found in the *Marshi/Crickmayi* Zone of Europe and North America, together with loose fragments of *?Psiloceras erugatum* Buckman, coeval with the lowermost part of the Hettangian *Planorbis* Zone. About 80 m higher occur beds yielding *Psiloceras* cf. *P. rectocostatum* Hillebrandt, a species that gives name to an Andean biozone partially coeval with the *Johnstoni* and *Plicatulum* Subzones, upper *Planorbis* Zone. Other fossil groups recorded in Rhaetian strata of this section are foraminifers, ostracods and plant remains, the latter identified as *Zuberia* cf. *Z. zuberi* (Szaj.) Freng. and *Clathropteris* sp. The section was also sampled for conodonts and radiolarians, thus far with negative results. A paleomagnetic study is underway. This is a contribution to IGCP Project 458 “Triassic/Jurassic boundary events”.

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THE LATE TRIASSIC TO EARLY JURASSIC SUCCESSION IN SOMERSET, ENGLAND: PALYNOSTRATIGRAPHIC AND OTHER CONSIDERATIONS

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The late Triassic to early Jurassic sequence exposed on the west Somerset coast comprises the Mercia Mudstone Group (MMG) and succeeding Penarth (PG) and Lias (LG) groups. A section on this coast, at St Audrie's Bay, is a candidate GSSP for the base of the Jurassic. The palynology of the Norian to Hettangian succession has been documented here and in other coastal sections, and in nearby boreholes at Selworthy and Brent Knoll.

Palynomorph assemblages have been recovered from the upper 45m of the MMG and the succeeding PG and LG in the candidate GSSP. The lowest assemblage, from the upper part of the Twynning Mudstone Formation, comprises a miospore association dominated by circumpolles. Assemblages from between that level and the highest part of the overlying Blue Anchor Formation comprise similar miospore associations but marine palynomorphs appear in the highest 2m of that formation, at the top of the MMG. Assemblages from the succeeding PG and LG comprise both miospores and marine palynomorphs, including dinoflagellate cysts and acritarchs. The miospore associations show a gradual, but progressive, increase in diversity upwards, through the Blue Anchor Formation and into the succeeding PG. This trend culminates in the Lilstock Formation, at the top of the PG, and associations from the succeeding LG are appreciably less diverse. The miospore succession includes important first and last occurrences. The last occurrences of *Ovalipollis pseudoalatus* and *Rhaetipollis germanicus*, for example, are in the upper PG and basal LG respectively, above the appearance, in the Blue Anchor Formation, of *Quadraeculina anellaeformis* which ranges up into the Jurassic. Marine palynomorphs are scarce in the Blue Anchor Formation but important in PG assemblages in which the dinoflagellate cyst *Rhaetogonyaulax rhaetica* is common. A decrease in the abundance of *R. rhaetica* in the upper PG marks the top of the Rr dinoflagellate cyst biozone, though the taxon ranges into the LG. Changes in the miospore associations reflect factors that influenced terrestrial environments. The organic-walled microplankton associations were introduced during a transgression in Rhaetian times and reflect subsequent variations in that marine environment. Very similar palynomorph distributions occur in the successions proved in the Brent Knoll and Selworthy boreholes.

The changes observed in the palynomorph succession in Somerset have been documented consistently from sections elsewhere in Britain and in Europe. In the candidate GSSP and other sections in Somerset these changes are calibrated with the occurrences of other fossil groups, such as conodonts and ammonites, and with microfossil biostratigraphic schemes, magnetic reversals and isotope variations, providing a broad basis for correlation with sequences elsewhere, including ones in continental facies.

JURASSIC AMMONOIDS BIOCHRONOLOGY IN THE TIBETAN HIMALAYAS

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The recent collections in Tibet allow to the establishment of Jurassic ammonoid succession ranging from Hettangian to Tithonian with a regional definition of the Triassic-Jurassic and Jurassic-Cretaceous system boundaries. Intercontinental correlation can be made at zonal level for some of intervals; whereas some of Jurassic substages are represented by hiati or none-marine facies in the Tibetan Himalayas.

Lower and Middle Hettangian, Lower Sinemurian and Upper Toarcian of the Lower Jurassic are established; the Upper Sinemurian may be represented by hiatus. However, a carbonate platform environment existed for a considerable length from Pliensbachian to early Bajocian times in the shelf of the Himalayan sea. Only Lower Bajocian, Upper Bathonian and Lower Callovian are documented by ammonite evidence in Middle Jurassic with a hiatus of 8 myr duration including the Upper Bajocian to Middle Bathonian. Upper Jurassic ammonites are entirely inhibited by highly endemic faunas, suggesting a close affinity to the SW Pacific domain. Based on the collections of samples in situ, Middle Oxfordian, Upper Kimmeridgian, as well as both Lower and Upper Tithonian are established. The Triassic/Jurassic boundary is indicated by the *Choristoceras* and *Psiloceras* assemblages; the Jurassic/Cretaceous boundary is indicated by the youngest Jurassic assemblage, *Corongoceras-Himalayites* and the earliest Cretaceous *Spiticeras* assemblage in the region.

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