

## **SLEADS (Salt Lakes, Evaporites, Aeolian Deposits) Workshop**

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beneath the south Portuguese terrane is distinct from that beneath the rest of Iberia which is generally composed of three layers totaling approximately 30 km in thickness.

The next day saw some elaboration of the characteristics of the Iberian terranes in terms of igneous, tectonothermal, stratigraphic and paleontological data. Igneous papers dealt with the petrology, geometry and ages of plutons and their contact metamorphism and relationship to deformation. Tectonothermal evolution of terranes in the axial zone of the Pyrenées and in ophiolitic complexes in Iberia was expounded, and a comparison between the terranes in the South Portuguese Zone and southwest England was made. Stratigraphic analyses of the Late Precambrian and Early Paleozoic in the southwestern Spanish Meseta, central Ossa-Morena terrane and in central Portugal were presented. Paleobiogeography of Late Cambrian trilobites, Ordovician faunas and Devonian-Carboniferous palynology of the South Portuguese Zone were applied to terrane analysis. The day ended with presentation of a model for the evolution of the Iberian terranes by E. Martinez-Garcia involving closing of the Hesperian Ocean beginning in the Early Ordovician, initial collision during Late Silurian-Early Devonian followed by progressive convergence throughout Devonian and Carboniferous and ending in the Permian.

The next day was devoted to a survey of data relating to Paleozoic terranes in Europe, specifically the French Hercynides, Armorica, the Silesian-Polish Massif, the Eastern Alps, the Caledonides in Scotland, Eire, Anglesey, Poland, Scandinavia and Spitsbergen. P. Matte presented a model for the Variscan Orogen in Western Europe involving the closure of two oceans: the Rheic and Galician-Massif Central oceans, between 420 and 280 Ma with initial collision occurring as early as 380 Ma ago. Migration of deformation, metamorphism and plutonism away from the sutures through time is a characteristic of the Variscan Orogen.

One day was devoted to the terranes in the Appalachian and Mauritanide-Rockelide Orogens. Appalachian papers dealt with various aspects of the terranes, such as the Grenvillian and Avalonian basements, sedimentology and accretionary history, plutonism and metamorphism. R.D. Dallmeyer and M. Villeneuve presented a comparison between an evolutionary model for the southern Mauritanides and southern Appalachians. They recognize three orogenic phases: (i) Pan-African I produced by the collision of a western block and the Western African craton yielding cooling ages of approximately 650 Ma, (ii) Pan-African II structures yielding approximately 560 Ma cooling ages, and (iii) Hercynian structures yielding approximately 280 Ma cooling ages. These are comparable to terranes and events recorded south of the Brunswick-

Altamaha Magnetic Anomaly in the southern Appalachians. This session ended with a general paper by T.P. Trurnit on the sequence that terranes pass through during global tectonic megacycles.

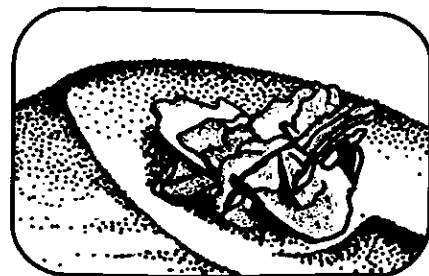
The final day of the conference was devoted to map compilation workshops to define the legends for maps relevant to terrane analysis. These workshops were preceded by a lecture by J.D. Keppie on the methodology of producing metallotectonic maps as one of the products of Project 233. The map workshops produced thematic map legends and the concept of time slice maps which could combine the various types of thematic data on individual maps. Projected map scale is 1:5,000,000 and the Decade of North American Geology Time Scale will be used. The first map will be a Preliminary Terrane Map of the Circum-Atlantic Paleozoic Orogens with the terranes classified as in the Circum-Pacific Terrane Map, and also showing overstep sequences and stitching plutons.

Two six-day field trips were run in association with the conference with the intent of critically evaluating the definition of the terranes in Iberia, and defining problems critical to their identification and accretionary history which could be tackled by co-operative research under the auspices of Project 233. The pre-conference field trip was led by E. Martinez-Garcia and J. I. Gil Iburguchi, and involved a geotraverse along the northern coast of Spain. The post-conference field trip involved a geotraverse across the southern terranes in Spain from Toledo to Huelva, and was led by E. Martinez-Garcia, P. Herranz, M.A. de San Jose, A. Perejon, J. M. Gonzalez-Casado, A. Pieren, O. Apalategui, L. Eguiluz and J.L. Hernandez-Enrile. Two excellent guide books were prepared and the trips were very well run. A typical daily schedule involved a full day (0830-1930 hours) of field work followed by an evening workshop — intensive, but very stimulating! All participants learned a great deal about Iberian geology which would have been difficult any other way as most of the literature is in Spanish or Portuguese. As a result of the intense discussion throughout the two trips, a sharper definition of the terranes in Iberia will be available for the Preliminary Terrane Map of the Circum-Atlantic Paleozoic Orogens. Participants should also have a clearer idea of how to define terranes in their own parts of the orogens as a result of these working field trips.

A program with abstracts and a list of participants was published for the meeting. A volume of collected papers will be published.

Enrique Martinez-Garcia and his colleagues are to be congratulated on organizing such an excellent conference and field trips, and for publishing the first treatment of Iberian geology in terms of terranes in English.

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## SLEADS (Salt Lakes, Evaporites, Aeolian Deposits) Workshop

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Although originally designed to focus on geological and environmental research in the Australian arid zones, the last two SLEADS conferences have included a much broader spectrum of international involvement (see *Palaeogeography, Palaeoclimatology, Palaeoecology* v. 54). This workshop, the fifth of its kind and held at Australian National University in Canberra 30-31 March 1987, saw papers presented by scientists from six nations, discussing regions from Saskatchewan to India, China, and, of course, Australia. Unfortunately, the collected papers from this conference will not be published except in the workshop abstracts (available from Patrick De Deckker, same address as above).

In his discussion of the late Pleistocene megalake paleohydrological problem, John Chappell demonstrated that if evaporation rates and groundwater regimes were held constant, then under steady state conditions, either rainfall or runoff must increase in order to fill the paleolakes to the levels that they occupied previously. Using conical lake geometry and a dynamic model with very rapid runoff followed by slow evaporation, however, the lakes could be maintained with only double the present rainfall. Chappell noted that to prove that the dynamic model applied would require more detailed survey and lake level fluctuation data. Unfortunately, the paper ignored groundwater effects and the potential differences in runoff as a function of vegetation changes, which elsewhere in Australia have had significant effects (Kershaw, pers. comm.).

Based on 7000 Australian Pleistocene dune orientations and 700 wind monitors, Bob Wasson *et al.* lucidly demonstrated that modern winds cross-cut dune field trends, especially near Perth and the Murray Delta. Late Holocene patterns do not match modern or 18 ka patterns. The modern wind

vortex centered near Lake Amadeus did not correlate with the 18 ka vortex in size or location. At 18 ka, they showed that the wind patterns were generally more zonal and stronger, the jetstream was unmoved, and the subtropical anticyclonic belt was further north, near its present winter position.

Since foram diameters and species diversity fell inland, Rao *et al.*, concluded that the marine forams found up to 800 km inland in the Thar Desert, India, were primarily derived from marine beaches or the continental shelf by eolian suspension of the low density tests. They felt sources such as the nearby modern foram-bearing lakes, the Ranns of Kutch, and Tertiary meliolic rocks were less important on the basis of the fauna collections. In the subsequent discussion, De Deckker suggested that Sr isotopes would solve the source problems. The conclusions of this paper were hampered by the lack of statistical population studies for the five potential sources and the dunes.

Several papers centered on discussions of the hydrology and sedimentology of salt lake regions.

At Spring Lake, Northern Territory, Gerry Jacobson found that groundwater flowed under the dunes to rise in the playa bottoms. Although the dunes trapped freshwater lenses above older salt brines, recharge occurred only in the dune margins where the water table was less than 1 m deep. Drought produced gypsum flats and terraces, while playa capture has occurred as the systems age causing salt flat formation as the water table recedes.

As might be expected at the downstream end of the Wallandra Lakes system in the Prungle Lakes deep basin, John Magee found varve-like couplets of reversely graded gypsum crystals intercalated with normally graded detrital layers reflecting a sequence of flooding-drying cycles. Sediments were displaced by primary celestite ( $\text{SrSO}_4$ ). Terrigenous clays, biogenic carbonates, and organic-rich layers occurring nearshore flanked ridges composed of cross-bedded eolian gypsum nodules and clay pellets.

An enthusiastic Bill Last and L. Slezak described a hypersaline meromictic lake, Freelight Lake, near Moosejaw, Saskatchewan, where they recognized at least six sedimentary-geochemical facies, ranging from a colluvial margin and exposed multi-mineralic carbonate-gypsum mudflats to a shallow water algal mat precipitating aragonite leading into the deep basin where debris fans of organic- and carbonate-rich sediments interfingered with mirabellite ( $\text{NaSO}_4$ ). The chemocline occurring at 5 m simultaneously with a temperature minimum was recognized by increases in  $\text{H}_2\text{S}$ ,  $\text{Na}^+$ ,  $\text{SO}_4^{2-}$  and  $\text{CO}_3^{2-}$  concentrations. Sedimentation rates of  $2 \text{ cm}\cdot\text{yr}^{-1}$  approximated those necessary to precipitate the 40 m of salt in the saline giants over 5 ka, according to the authors.

Patrick De Deckker and Bill Last discovered protodolomite in both the bottom "yogurt" and as whittings in lakes near Colac, Victoria. Fauna in the lakes reflected differences in clarity, hydrology, and chemistry, while the sediments in most contained at least 40% dolomite. With a Mg/Ca ratio of at least 15, all the lakes were extremely poor in  $\text{Ca}^{2+}$  and  $\text{SO}_4^{2-}$  but were oversaturated with respect to dolomite, magnesite, hydromagnesite, monohydrocalcite, and halite.

In West Basin Lake, Victoria, a saline meromictic lake containing an  $\text{H}_2\text{S}$ -rich gittiya with dolomite, calcite, monohydrocalcite, and magnesite in the deep basin, Bill Last and Patrick De Deckker found active stromatolites. Nearshore penecontemporaneous cementation had produced boundstone magnesite pavements and beachrock, while in the vadose zone, hydromagnesite crystals had been pseudomorphed by dolomite. Generally, they felt the sediments became less endogenic with depth in cores.

For many years in Australia, a controversy regarding the source(s) of the salt in the salt lakes has raged. To many geochemists this seems astonishing. Until recently, relict seawater remaining since the last transgression or aerosol salt were considered to be the only possible sources due to the similarity of the major element chemistry with that of modern ocean water. Contributions from connate waters or rock-water interactions were considered insignificant or even impossible. Several papers during the conference attacked this view.

In the Great Artesian Basin Jurassic and Cretaceous aquifers, Andy Herczeg *et al.* found that  $\delta^{13}\text{C}$  values increased with total alkalinity due to organic reductions producing  $\text{CO}_2$ . The 1.0 Ma discharge water had reduced  $\text{Na}^+$  and  $\text{K}^+$  concentrations due to reverse weathering reactions with clays that did not significantly affect the aquifer porosity, according to Herczeg.

Allan Chivas *et al.* found that brines from Lake Buchanan, Australia, could not be produced by mixing modern rain water with marine water. Using  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios, they proved that the brines most closely matched local rock ratios, while  $^{34}\text{S}/^{32}\text{S}$  ratios suggested that less than half the  $\text{SO}_4^{2-}$  resulted from aerosol sources, but the remainder derived from weathering Cretaceous rocks.

In Western Australia lakes, Berry Lyon *et al.* found pH values as low as 2.3 and extremely variable Fe concentrations which were not a function of Eh or Cl<sup>-</sup>, but were related to the local watershed rock type, further supporting the importance of water-rock reactions in brine salts derivation.

Since vadose wetting-drying reactions tend to greatly increase major element cation concentrations compared with salinity, while phreatic reactions reduce these back to seawater-like values, Lyons could account for all the variations seen in Australian lakes with these reactions. In the animated discussion

following this paper, which continued long after the excellent Vietnamese smorgasbord dinner, the question of the vadose zone reactions could not be resolved to the protagonist's satisfaction.

Several papers were devoted to the application of dating methods to the Quaternary deposits related to salt lakes.

In their  $^{36}\text{Cl}$  dating method, Allan Chivas *et al.* used 12 MeV accelerated ions from Cs-irradiated AgCl sources counted in isobutane-filled heavy ion counters. Although  $^{36}\text{Cl}/\text{Cl}$  only averages  $10^{-13}$  to  $10^{-15}$  naturally, the mid-century "bomb spike" in Australian dunes and Raleigh distillation effects were recognized. Australian brine  $^{36}\text{Cl}/\text{Cl}$  ratios matched those of catchment sources rather than sea water. Since  $^{36}\text{Cl}$  ages at Searles Lake compared "reasonably" with  $^{14}\text{C}$ , Th/U, and paleomagnetic ages, the authors are now determining the age of the 3 m Lake Nullabar salt speleothem.

In attempting to  $^{14}\text{C}$  date authigenic pedogenic carbonate from Cheng Jia Wo, China, John Head found few soil bacteria and plentiful low molecular weight polysaccharides in soil nodules laced with finely disseminated calcium carbonate. Although  $\delta^{13}\text{C}$  values were consistent at approximately -6‰ for all fractions, Head's acetic acid leach ages were consistently younger than HCl leach ages, yet both fractions resulted in identical ages regardless of depth down-section. A lack of thin section work and consistency tests within and along the soil horizons mar the conclusions regarding the method's usefulness.

In  $^{230}\text{Th}/^{234}\text{U}$  dating pedogenic carbonates and gypsums of central Australia, Andy Herczeg corrected for detrital Th and U by calculating isotope ratios from both the acid leach and the insoluble residue fractions. Although Th/U ages were inconsistent for bones, some aragonitic mollusc shells compared with gastropod tests, ages for a few shells did agree with  $^{14}\text{C}$  ages. For the pedogenic carbonates, however, Herczeg's Th/U ages did not agree with thermoluminescence or  $^{14}\text{C}$  ages. The method probably failed because the author did not consider the possibility of open system U uptake or multiple sources for detrital U and Th.

Gerry Jacobsen *et al.* reported that ESR ages for Spring Lake gypsums and gypcrettes gave consistent ages down-core, although they had not been tested against other dating methods. In this attempt, annual dose rates were back calculated by assuming  $^{230}\text{Th}/^{234}\text{U}$  and  $^{14}\text{C}$  ages on an ESR-"dated" pedogenic carbonate were correct. Since both Th/U and  $^{14}\text{C}$  are, at best, problematic, and at worst, incorrect, for dating pedogenic carbonates, the dose rate calculation and the consequent ages must be considered inadequate, until proper dose rates can be calculated by accepted methods, and the ages tested against proven methods.

Using induced magnetic field fingerprinting of magnetic minerals, Robin Clark and

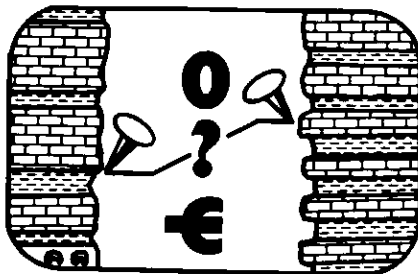
F. Oldfield found that colour differences in the Strezlecki dune field, Australia, were independent from the magnetic signatures which depended on location within the field and position within the dune.

In one of longest complete cores from Australia, the 22 m Lake Terang core, Charlie Barton *et al.* determined that although the paleomagnetic Q-ratio (intensity/susceptibility) paralleled the organic content curve, the former did not agree with median destructive field data regarding the magnetic mineral type and stability. Neither the Mungo nor Laschamp paleomagnetic inclination excursions were seen, nor was there any correlation with other Australian sequences, and dates were reported only for the upper portion of the core. Hence, no sedimentation rate could be estimated, although the authors claimed this core represents about 100,000 years of sedimentation.

Two papers to be presented by Chinese scholars were unfortunately not given due to inadequate translation facilities, although the authors were available to answer questions arising from the abstracts. Since such problems often hamper international conferences, it behooves organizers to consult speakers in advance to further unbiased scientific discussion.

Although the scientific calibre of the meeting was generally high, poor communication skills overshadowed several presentations. When will our profession learn that the obvious importance of the work cannot carry the burden in lieu of a well-organized, audible, concise, coherent argument illustrated with neat, well-labelled, legible, colourful diagrams? In interdisciplinary meetings such as this, moreover, it is often necessary to downplay the technical language and simplify the applications of the more peripheral techniques in order to maximize their impact.

By the end of the conference, it was obvious that arid region paleoenvironmental studies are severely limited by a dearth of proven dating methods. With the exception of  $^{14}\text{C}$  for fossils and charcoal and  $^{36}\text{Cl}$  for water or NaCl, the latter method still in its infancy, no methods have yet successfully dated either the typical mineral deposits or the fossils. Consequently, it is difficult, if not impossible, to estimate sedimentation rates and to time environmental changes, particularly beyond the range of  $^{14}\text{C}$ . If our knowledge of arid regions is to progress, it can be only hoped that the next few years will see the perfection and vindication of dating techniques for older fossils, pedogenic carbonates, and other minerals, and that methods can be developed that will span the  $^{14}\text{C}$ —K/Ar gap.



## Final Cambro-Ordovician Boundary Meeting, People's Republic of China

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The final meeting of the International Working Group on the Cambro-Ordovician Boundary (IUGS Commission on Stratigraphy) was held at Hunjiang (pop. about 150,000) in the Province of Jilin (once part of Manchuria), People's Republic of China in late July-early August, 1986. It came after some 12 years of formal and informal discussions and site visits by geologists interested in the Cambro-Ordovician boundary.

Some 24 foreign delegates from Australia, Belgium, Canada, France, Great Britain, Italy, Japan, North Korea, Norway, Sweden, United States, and West Germany met with 46 Chinese colleagues from local geological bodies and colleges and the Nanjing Institute of Geology and Paleontology. The section near the village of Dayangcha, 25 km from Hunjiang was chosen by Chinese geologists as their best candidate for consideration as the Cambro-Ordovician boundary stratotype. The meeting lasted five days with two days spent examining and collecting from the section and three days spent in the nearby city of Hunjiang where a number of formal presentations were made on the sedimentology and biostratigraphy of the Dayangcha section, on other potential boundary stratotypes around the world and on the biostratigraphy of various fossil groups. The last stage of the meeting consisted of open discussion and debate.

The strata crop out along a road and creek bank, and considerable work had been done by the villagers to expose and label the section, including diverting the creek. Several hundred metres of carbonate rocks are exposed and other sections in nearby quarries also contain boundary interval strata. The consensus of most workers was that the carbonate strata were deposited under deep shelf conditions, with just one horizon with stromatolites indicating a shallowing event. A good variety of fossils is present especially conodonts, trilobites, graptolites and

acritarchs. Geologists with the Nanjing Institute of Geology and Paleontology had done a variety of detailed studies in the last few years and their results were presented at the meeting, orally and in book form.

*Aspects of Cambrian-Ordovician Boundary in Dayangcha, China*, a large book of 410 pages and 98 plates, was edited by the project leader Chen Jun-Yuan and copies can be obtained from him at the Nanjing Institute (price not known). The volume covers the lithostratigraphy, petrography, depositional environments, clay mineralogy, rare earth and other trace elements in apatite across the proposed boundary, Rb-Sr dating of the sediments, and biostratigraphy and taxonomy of the conodonts, graptolites, trilobites and acritarchs. It is a remarkable piece of work considering it was but a few years from start to finish for this entire research effort.

The criteria for a Cambro-Ordovician boundary stratotype were formalized as a number of non-binding resolutions at the 1985 meeting in Calgary. Conodonts are to be the primary guide fossils as many of their species are cosmopolitan and a number of new evolutionary forms, particularly species of *Cordylodus*, originated around the time under consideration. Their presence in a wide variety of lithologies and environments, and commonly in abundance, make them "ideal" index fossils. A second criterion was that the boundary is to be drawn at an horizon close to the appearance of the first nematophorous graptolites, which will be used as the field guide for the boundary. Although graptolites have been a traditional guide fossil for the base of the Ordovician, their rarity or absence in shallow platform carbonates and their difficult taxonomy has prevented their use as the key index fossil group. Two candidate species of *Cordylodus* (*C. intermedius* and *C. lindstromi*) have been proposed for the boundary definition and the use of the first appearance of either will raise the boundary a little higher than an earlier candidate, *i.e.*, the first appearance of *Cordylodus proavus*. Stability is also promoted as the first appearance of one of the subspecies of the graptolite *Rhabdinopora flabelliformis* (formerly *Dictyonema flabelliforme*) was used in the past to identify the base of the Ordovician in graptolitic sequences. Unfortunately, trilobites have proven to be too endemic for use in global correlation.

A third criterion, and one agreed on for the first time in consideration of an international boundary stratotype, was that the section has potential for the use of paleomagnetism, geochemistry and other non-biological correlation tools. This resolution was prompted by the finding by J.L. Kirschvink and A. Kobayashi-Kirschvink (Cal Tech)(unpublished) of a magnetic polarity flip in latest Cambrian strata in the Maly-Karatau Range, Kazakhstan, USSR. This information awaits confirmation from