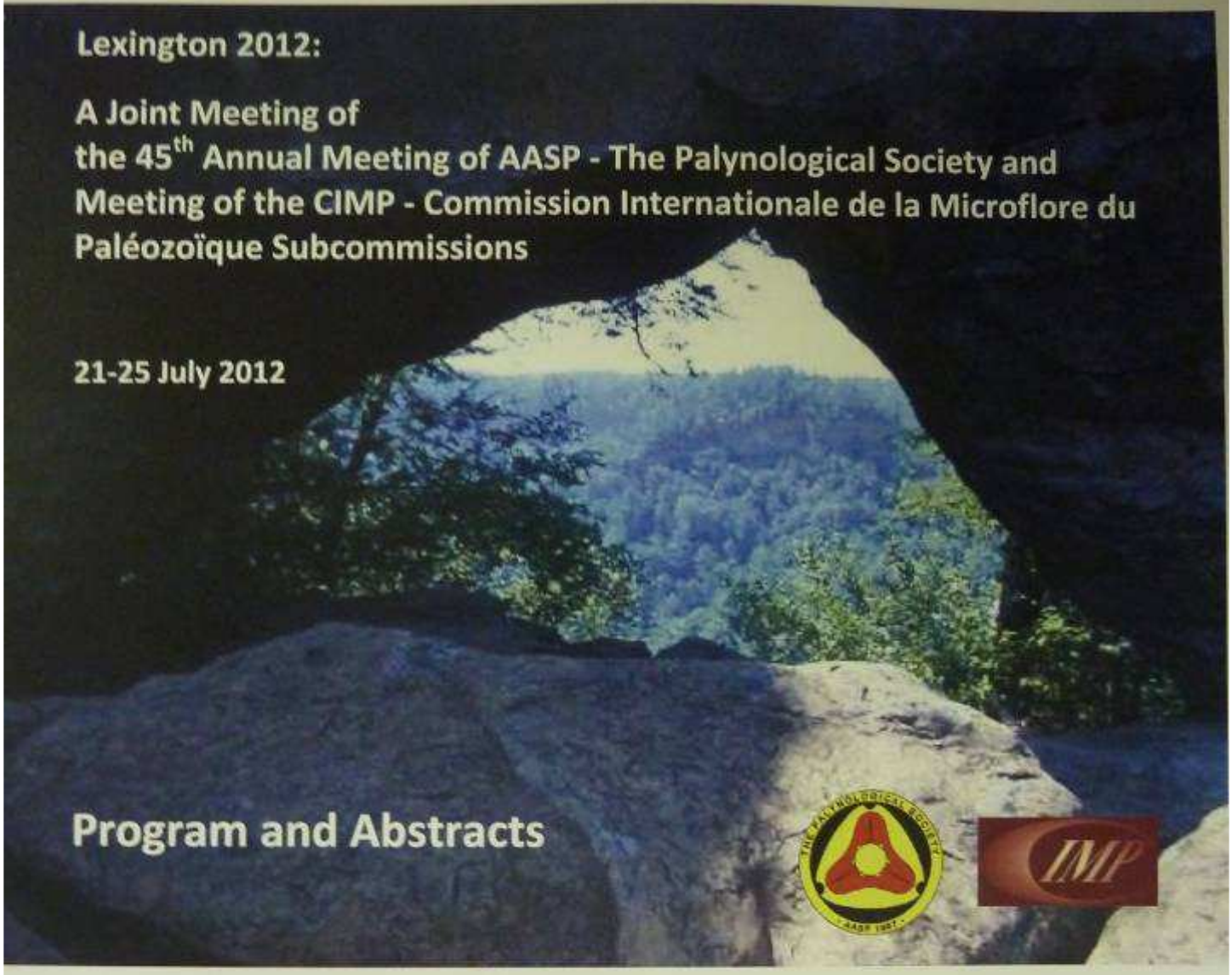
Kentucky Geological Survey
University of Kentucky
Lexington, KY

Department of Earth and Space Sciences
Morehead State University
Morehead, KY

Lexington 2012:

A Joint Meeting of the 45th Annual Meeting of AASP - The Palynological Society and Meeting of the CIMP - Commission Internationale de la Microflore du Paléozoïque Subcommissions

21-25 July 2012



Program and Abstracts

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Palynological record of Devonian and Pennsylvanian units in the Espejos Range, western Santa Cruz de la Sierra, central Bolivia

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As part of a major Carboniferous-Permian project in Bolivia between 2007 and 2009 (undertaken by geologists from different countries and funded by Spain), palynological investigations were carried out to test the Pennsylvanian biostratigraphic scheme (KA, RS, BC, MR and TB zones) in the central portion of the Tarija-Chaco Basin and its aid in stratigraphic discrimination. This contribution presents the palynological results of several sections located in the Espejos range along the La Angostura-Bermejo-Samaipata-Mairana highway, west of Santa Cruz de la Sierra.

The geology of the Espejos range is tectonically complex consisting of faulted anticlines and synclines of Devonian to Permian and Mesozoic and Cenozoic strata. Cenozoic and Mesozoic strata crop out on the east side of the range, whereas the Paleozoic succession appears after La Angostura. Different Devonian, Carboniferous and less frequently Permian rocks (at La Angostura) crop out to the west up to Mairana. The stratigraphic units are generally in faulted contact and structural repetition of units is quite common.

Pennsylvanian units are represented by the Machareti (McG) and Mandiyuti (MdG) groups which consist of interbedded sandstone and diamictite units with minor shale and mudstone beds. Each

group has traditionally been divided into formations based on the first occurrence of sandstone within mudstone- or diamictite-dominated units. The McG is divided into five formations in Bolivia (oldest to youngest): Tupambi, Itacuami, Chorro, Tarija and Taiguati. The MdG consists of the Escarpment and San Telmo formations. This lithostratigraphic scheme is well applied in southern Tarija-Chaco Basin where contacts between sandstone-dominated (Tupambi, Chorro) and mudstone-diamictite-dominated (Itacuami, Tarija/Tupambi) units is clear. However, to the north unit contacts are difficult to establish due to increased interbedding of sandstone and diamictite units, reinforced by tectonic effects. This study focuses largely on the McG because the MdG in this area, mainly exposed in the upper part of the mountains, is dominantly red in color (four samples were barren).

Twenty six samples were taken from the McG at five different locations between Mairana and Bermejo. From west to east, near Mairana one productive sample was taken from a grey muddy diamictite whilst other seven from reddish and greenish grey muddy diamictites were barren. Two productive samples were taken from grey diamictites 24 km from Samaipata toward Bermejo (Point 1). Fourteen kilometers ahead (Point 3), one barren sample taken from light grey very fine-grained sandstone over Devonian rocks (faulted contact) and up-section, two productive samples were collected from grey diamictites. Thirteen kilometers ahead, a thick McG section (Ginger's Paradise, ca. 500 m) was sampled. From this area, eleven grey and greenish-grey mudstone and diamictites were productive whilst two reddish brown mudstones were barren.

The palynoassemblages recovered from McG are composed of biostratigraphically important indigenous species such as *Cristatisporites chacoparanensis*, *Cristatisporites* spp., *Dictyotriletes bireticulatus*, *Granulatisporites varigranifer*, *Verrucosisporites morulatus*, *V. patelliformis*, *V. quassigobbettii*, *Endosporites rhytidosaccus*, *Vallatisporites arcuatus*, *Costatacyclus crenatus*, *Potonieisporites magnus*. Abundant reworked palynomorphs from Devonian (e.g., *Umbellasphaeridium saharicum*, *Maranhites* spp., *Retispora lepidophyta*, *Grandispora pseudoreticulatus*) and Mississippian (e.g., *Pustulatisporites gibberosus*, *Cristatisporites peruvianus*, *Cordylosporites magnidictyus*) rocks are present, as well as from the underlying Bashkirian KA-RS zones in agreement with previous works (e.g., *Schopfipollenites ellipsoides*). The stratigraphic distribution of the indigenous species supports the correlation of all assemblages to the Bashkirian-Moscovian *D. bireticulatus–C. chacoparanensis* (BC) Zone, reinforced by the presence of exclusive forms such as *C. chacoparanensis*, *D. bireticulatus*, *E. rhytidosaccus*, and *V. morulatus*. It corresponds to the Tarija Formation and the base of the Escarpment Formation in northern Argentina and southern Bolivia (Tarija-Chaco Basin). The diamictitic units bearing the BC Zone in the studied area are similar lithologically to the Tarija Formation in southern part of the basin, thus confirming their stratigraphic attribution.

Three productive samples were collected from Los Monos/Iquiri mudstones (Givetian-Frasnian) under a faulted contact with the Carboniferous (Point 2, ten km from previous Point 1), which yielded abundant and diverse well preserved palynomorphs (spores, acritarchs, prasinophytes and chitinozoans). Species such as *Lunulidia micropunctata*, *Maranhites* spp., *Samarisporites triangulatus*, *Angochitina mourai*, *Lagenochitina avelinoi*, and *Fungochitina pilosa* allowed the attribution of these assemblages to the late Givetian - late Frasnian.

Identification of palynomorphs of the BC Zone in diamictites below the Escarpment Formation in the central Tarija-Chaco Basin supports the previous biostratigraphic scheme for the Machareti Group developed from deposits in northern Argentina and southern Bolivia. Even though tectonic complexity disrupts the succession, this work demonstrates that the biostratigraphic zones follow lithostratigraphic boundaries across the basin and that the lithologic changes from south to north in the Tarija-Chaco Basin are related to major shifts in paleoclimate during the Pennsylvanian.

Keywords: Palynostratigraphy, Machareti and Mandiyuti Groups, Pennsylvanian, Tarija-Chaco Basin, central Bolivia.

Palynology of the Devonian-Mississippian transition in western Montana: Three Forks, Sappington and Bakken formations

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Late Devonian-Early Mississippian strata east of the Antler continental borderlands in the incipient Central Montana Trough (CMT) are coeval with the Exshaw of Alberta and Bakken formations of the Williston intracratonic basin. Carbonates and siliciclastics of the Middle Famennian Three Forks Formation and latest Famennian-Tournaisian Sappington Formation are characterized by a facies change and pinch-out associated with high-amplitude eustatic base-level changes and widespread marine disconformities (i.e. 3rd-order sequences or 2nd-order icehouse episodicity occurring over several Ma). Like the Bakken, Sappington facies represent distally-thinning and -fining shoreface though offshore clastic-dominated ramp facies (black shale, burrowed siltstone and sandstone). Whereas South American and eastern North American palynology from the middle Famennian Tournaisian interval (~6 Ma) has been well studied, spore and pollen assemblages from Montana are not known. Black and dark green shales from CMT outcrops show promising initial results and work has been extended to well cores in NW Montana.

Two palynologically productive samples from the Trident Member at Milligan Canyon on the Lombard Thrust and six from Logan Gulch on the Horseshoe Hills in Montana yielded low diverse palynoassemblages, with different preservations (e.g., orange well-preserved, dark brown and black poorly preserved palynomorphs). The Milligan assemblages (MEAs) and the older three samples from Logan (LAs1) are mostly composed of cosmopolitan, long ranging phytoplankton species that are recorded from the Frasnian to the Strunian (e.g., *Cymatiosphaera perimembrana* Staplin, *Elektoriskos dolos* Wicander and Loeblich, *Gorgonisphaeridium ohioense* (Winslow) Wicander, *Gorgonisphaeridium absitum* Wicander, *Gorgonisphaeridium plerispinosum* Wicander, *Maranhites britoi* Stockmans and Willière, *Michrystridium adductum* Wicander, *Solisphaeridium astrum* Wicander, *Stellinium comptum* Wicander and Loeblich, *Unellium piriforme* Rauscher, *Unellium lunatum* (Stockmans and Willière) Eisenack et al.). Some species have a more restricted stratigraphic range (*Ammonidium garrasinoi* Ottone from Givetian to late Frasnian, *Gorgonisphaeridium evexispinosum* Wicander from the Famennian, *Unellium elongatum* Wicander and *Pterospermella latibalteus* Wicander from mid-late Famennian, *Exilisphaeridium simplex* Wicander from ?Strunian, and *Leiotriletes struniensis* Moreau-Benoit from Strunian palynofloras). Hence, these marine assemblages (MEAs and LAs1) are likely pre-Strunian Famennian in age.

Four samples processed from very carbonaceous lower Sappington black shales at Milligan East were barren and one from the very thin, basal brown shale at Logan (LAs2) yielded only leiosphaerids with an internal folding named here "monosacoid" due to its similarity with the *Plicatipollenites* and *Potonieisporites* monosaccate pollen grains.

Two samples processed from USGS Bakken cores from NW Montana (Big Sky 1, lower Bakken at 9926 and 9920 ft), yielded two different assemblages. The older one is composed of a fairly well preserved assemblage with the same species recorded in MEAs and LAs1. Hence, a correlation between

them is here proposed. The other assemblage yielded less diverse acritarchs (*Gorgonisphaeridium ohioense, G. absitum, Hemiruptia legaultii* Ottone) and abundant leiosphaerids of different sizes (ca. 50 up to 400 µm) and morphologies (i.e., without folding, with random folding, with monosacoid folding). Although this assemblage has no biostratigraphical useful species, its stratigraphic position and the presence of leiosphaeirids with monosacoid folding suggest correlation to the LAs2, in a lagoonal depocentre.

From the basal part of the Lodgepole depositional system (upper Sappington shale) at Logan, dark brown shales yielded badly preserved, dark brown to black trilete spores with quite abundant *Botryococcus braunii* Kützing. A Tournaisian age is given to the upper Sappington (LAs3) based on few biostratigraphically useful species such as *Waltzispora polita* (Hoffmeister et al.) Smith and Butterworth, *Leiotriletes sphaerotriangulus* (Loose) Potonié and Kremp, *?Grandispora echinata* Hacquebard, and *Punctatisporites glaber* (Naumova) Playford.

The ages observed in this study agree with previous conodont work for the Three Forks Formation (Trident Member - middle Famennian *marginifera/trachytera* Zones), lower Sappington (*expansa* Zone), and for the upper Sappington black shale (Tournaisian *duplicata/sandbergi* Zones). The Strunian *praesulcata* Zone was previously defined in shales of the Unit 4 interbedded within the middle Sappington (reservoir) in the Bridger Range in Montana. A *Retispora lepidophyta* assemblage was found in the same unit. The latter was not observed here, but more detailed studies will be developed.

Evaporitic, shallow through deep marine rocks of the Three Forks and Sappington formations in western Montana represent local intrashelf troughs inboard of active Devonian-Mississippian arches along the Montana-Idaho border. Few of these units nor easily recognizable Sappington facies occur on these uplifted and down-dropped paleohighs that were rapidly buried by active Antler sedimentation. On the other hand, remarkably similar and widespread latest Famennian stacking patterns across the "more stable" part of the Montana craton (and other parts of the world) suggest primary global controls during abrupt late Famennian change in climate/eustasy, arborescence, and transition to a Carboniferous icehouse.

Keywords: Palynology; depositional setting; Bakken Three Forks and Sappington formations; Late Devonian; Early Mississippian; Montana, U.S.A.

Palynology and paleoenvironment of the Cisuralian Vitiacua Formation in southern Bolivia

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The Vitiacua Formation was previously described comprising of three transgressive restricted marine cycles ranging from lower to upper Permain and Triassic age. Similar units were correlated into Peru and associated with widespread volcanism and extension. This study presents new stratigraphic and palynologic data of the Vitiacua Formation from three locations in southern Bolivia: the La Yesera area

(West and Centre) and at Canaletas near Tarija. These outcrops overlie massive sandstones beds of the eolian to estuarine Cangapi Formation and are composed of thin grey and green silty micritic limestone beds that are interbedded with faintly laminated fissile shale with some silt and chert lenses.Overall thicknesses of the three sections are ca. 300 m.

Eight productive samples (of 14 samples processed) yielded 62 species of terrestrial palynomorphs of which 17 are spores (11 trilete and 6 monolete), 42 are pollen grains (11 monosaccate and bisaccate non-striate, and 31 striate and costate), and 3 species of algae. The well preserved Yesera Centre assemblage (YCA, one sample) is defined by the presence of several species of *Vittatina*, *Lunatisporites*, *Pakhapites* and *Lueckisporites virkkiae* (Potonié and Klaus) Klaus together with other species of *Hamiapollenites*, *Mabuitasaccites*, *Striomonosaccites*, *Striatoabieites*, *Striatopodocarpites*, *Weylandites*, and *Botryococcus brauni* Kützing. The well preserved Yesera West assemblage (YWA, three samples) is characterized by abundant to frequent monolete (e.g., *Polypodiisporites mutabilis* Balme, *Reticuloidosporites warchianus* Balme, *Thymospora rugulosa* Mautino et al.) and trilete spores (*Lundbladispora braziliensis* (Pant and Srivastava) Marques Toigo and Pons emend. Marques Toigo and Picarelli, *Convolutispora uruguaiensis* Mautino et al.) with subordinate algae and pollen grains (e.g., *Pteruchipollenites*, *Vitreisporites*). The Canaletas assemblage (CA, four samples) was poorly preserved but contained scarce pollen grains including *Lueckisporites virkkiae*, *Striatoabieites multistriatus* (Balme and Hennelly) Hart, *Pteruchipollenites indarraensis* (Segroves) Foster, and *Botryococcus brauni*. The YCA and CA are correlated to the Lower Member Assemblage (mid Asselian to early Sakmarian) of the Copacabana Formation at Apillapampa in central Bolivia. However, the samples collected at Yesera West are similar to the overlying Copacabana Coal Member (early Sakmarian- Artinskian?).

Diverse pollen grains (striate and non striate) of gymnospermous affinities are dominant in the YCA and CA, whereas notable pteridophytes, sphenophylls and lycopods are dominant in the YWA. These groups of plants characterized the terrestrial landscape of forests under a temperate climate belonging to the *Glossopteris* Flora during the Cisuralian in southern Bolivia. Algae such as *Botryococcus* indicate the development or input from fresh water environments (lakes and rivers). Calcareous muddy rocks, stromatolites, pyritization of palynomorphs in sample CICYTTP-PI 333 (VI3) at Canaletas and abundant fish teeth suggest shelf marine conditions, although not clear is the extent of hyposaline conditions. Some stratigraphic interpretations suggest extensive deepwater marine environments. However a paucity of marine macrofauna, significant volcaniclastics, rare paleosols and terrestrial palynoassemblages suggest cyclic, restricted mud-prone sedimentation in a back arc or rift setting.

These new stratigraphic data and palynology results from the lower Vitiacua Formation support correlative relationships and facies changes with respect to the upper Coal Member of the Copacabana Formation, in southern and central Bolivia. Radiometric data from interbedded tuffs in both places (Yesera and Canaletas) are under preparation.

Keywords: Palynology; sedimentology; paleoenvironment; Vitiacua Formation; Cisuralian; southern Bolivia.