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*Supplement of*

**Report on ICDP Deep Dust workshops: probing continental climate of  
the late Paleozoic icehouse–greenhouse transition and beyond**

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## Major Topics to Investigate

- 1- Equatorial paleoclimate of peak icehouse and icehouse collapse
- 2- Atmospheric dust and the Pangaeian megamonsoon
- 3- The later Permian— Extremes leading up to the Great Dying
- 4- The character and extent of the modern and fossil deep microbial biosphere
- 5- Auxiliary Science— Red-bed sedimentology, Pangaea paleogeography, induced seismicity, tectonics, geothermal energy, hydrogeology, drilling engineering

Questions	Major topic/s	Methods/Approaches
Did glaciation affect low latitudes? If so, what were the altitudinal limits of glaciation?	1	Coring of uplands to assess presence of ice-contact or periglacial indicators; correlation to paleoshorelines.
LPIA deglaciation: What is the far-field record (rate, effects), and what were the drivers? If CO <sub>2</sub> was a primary driver, what caused its extreme drawdown and subsequent rise on the scale of the entire Permian? What sources/sinks and mechanisms can explain the magnitude and frequency of glacial-interglacial CO <sub>2</sub> variations? Can we assess O <sub>2</sub> ?	1, 3	Assemble pCO <sub>2</sub> indicators (e.g. from paleosols; fluid inclusions?); carbon-cycle modeling incorporating dust-fertilization effects, weathering effects (on both long- and short timescales).
What role did mineral aerosols play in low-latitude climate? Can we quantify dust loading of the equatorial atmosphere, and the effects? How does dust provenance inform atmospheric circulation (w/ impact on understanding the megamonsoon)?	1, 2, 3	Reconstruction of dust loading (mass accumulation rates) by dating, quantitative cyclostratigraphy; dust provenance (detrital zircons, geochemistry; anisotropy of magnetic susceptibility); Fe geochemistry of dust deposits
What were spatiotemporal patterns of continental climate change— eg the character and pace of proposed eastwardly progressing aridification?	1, 2, 3	Indices of chemical weathering from loess, paleosols; compilation of arid-climate indicators; measurement of Sr isotopes; E-W correction.
Can we assess astronomical forcing of tropical climate and hydroclimate from the icehouse-greenhouse transition up toward the Great Dying? Are there changes in dominant periodicities, especially across the major deglaciation?	1, 2, 3	Conduct quantitative cyclostratigraphy throughout the cored successions.

Questions	Major topic/s	Methods/Approaches
How does Fe reactivity in dust deposits vary through time and (low latitude) space (E-W equatorial)?	1, 2, 3	Measure Fe reactivity through the cored intervals.
How extreme— in terms of hydroclimate, temperature, and pH (acidity) did equatorial environments become? What were the critical forcing factors (e.g. CO <sub>2</sub> , aerosols, continental position, monsoon)?	2 and 3	Assemble paleoclimate indicators, especially extent of arid-climate proxies, evaporite inclusions, organic geochemistry, etc., and proxies for atmospheric circulation (eg loess provenance).
What drove the end-Guadalupian biotic event? Is it related to climatic events? Was it spatially diachronous?	3	Assemble proxies and indicators for temperature/aridity etc— e.g. fluid inclusions, clumped isotopes (of eg pedogenic carbonate), weathering indices, organic biomarkers, etc. Correlate using e.g. palynofacies.
What is the extent of the (modern) microbial biosphere? How deep? What are the metabolic pathways for this life? Are As and Fe involved? Hydrocarbons?	4	Conduct clean sampling of pore fluids during coring.
Can we document a fossil microbial biosphere? What types of extremophiles might have existed? Under what pH/temp conditions?	4	Examine fluid inclusions in, e.g. evaporites. Document life forms, and accompanying pH and temperature proxies.
What is the origin of red beds, especially those formed far from localized volcanism? Did the Permian atmosphere promote iron reactivity? And/or O <sub>2</sub> levels (potentially obtainable via fluid inclusions?)	5	See above— measure Fe reactivity on loess and dust-associated deposits.
Can we constrain uplift rates of the Appalachian and Variscan orogens using thermochronology?	5	Conduct thermochronology through cored intervals.
What are baseline values of modern states such as geothermal gradients and micro seismicity in the target basins?	5	Instrument the boreholes for monitoring.
What is magnetic behavior during a superchron? Did orbital forcing affect magnetic field behavior?	5	Cyclostratigraphy
What was the paleogeography of Pangea during the Permian? Is it better captured by Pangea A or Pangea B (or neither)? What were the latitudes of the study sites, and their continentality?	5	Paleomagnetism through the cores.