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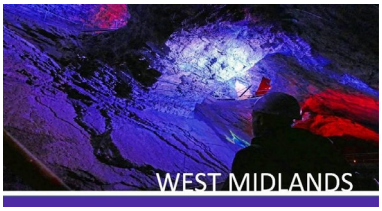

Entropy, Information Loss, and Sampling Design in High-Resolution Stratigraphy

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Abstract:

Modeling the vertical redistribution of sediment is of fundamental importance to a wide variety of disciplines, including stratigraphy and paleoceanography. Power law regression is commonly used to describe the relationship between sediment mixing coefficient and burial velocities. Bioturbation—the sediment particle translocation driven by the activity of bottom-living animals—creates a "divorce" between mixing intensity and mixed depth that fundamentally challenges our ability to resolve geologic time.

This presentation introduces first the geologic background for vertical sediment redistribution using the Gilbert-Shannon-Reeds model, originally conceived for the riffle shuffle of a deck of cards, applied to the rare case where the sediment keeps a layered structure after bioturbation, by shuffling n sedimentary laminae m times. The comparison of original vertical order with that after bioturbation shows that (3/2) $\log_2 n+c$ shuffles produce small total variation distance—or nearly random order. The asymptotic behavior of relative entropy demonstrates that entropy decays approximately linearly for $m < \log_2 n$, and exponentially for $m > \log_2 n$, providing a mathematical framework for assessing information loss in stratigraphy.

The practical implications for sampling design are addressed. In biostratigraphy and biodiversity studies, it is common to apply the binomial distribution to determine sample size for detecting multiple species, although the multinomial distribution should necessarily be used instead. When detecting K species together—each at potentially different relative abundances—the required sample size increases substantially. For

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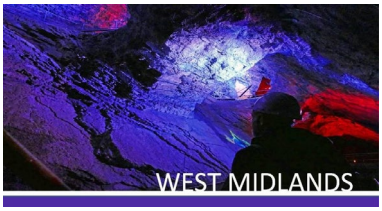

example, detecting 4 species together at 1% abundance with 99% confidence requires 599 specimens rather than the 500 typically used.

These entropy models clarify true time-order relationships when using the stratigraphic principle of superposition and have major influence on the fine-tuning of paleoceanographic reconstructions, adding information-theoretic value to the permutational theory of stratigraphic correlation.

About the Speaker:

Dr. Ali Talal Haidar obtained an M.Sc. degree from the University of Parma (1991), and a Ph.D. and a Post Doc. from ETHZ - The Swiss Federal Institute of Technology in Zurich (1997). He was a guest Professor at The University of North Carolina at Charlotte (UNCC), USA. He attended over 23 different types of courses of specialization (from nannofossil recognition under the light microscope to geo-statistics, stable isotope geochemistry, to geologic risk management, …). His research domain encompasses Oceanography, Micropaleontology, Biostratigraphy, Paleoecology, Sedimentology, and Petroleum Exploration. He has over 11 journal publications, in addition to international conference presentations in Europe and North America. He published in top international journals in his field of research (as Deep-sea Research and Cretaceous Research, among other journals). He is a chartered geologist (Italian National State Examination as a qualification to work in Applied Geology in Italy).

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