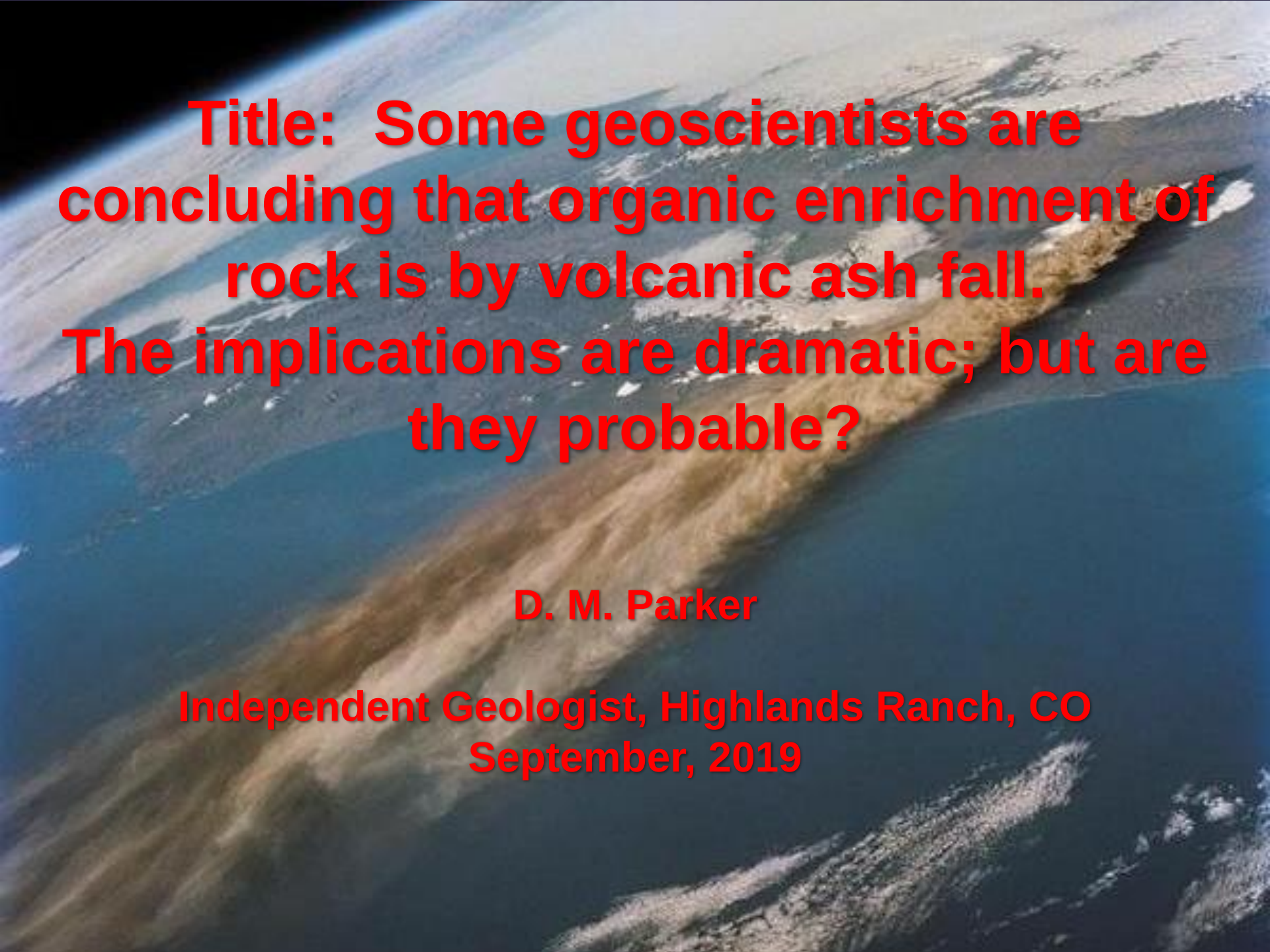
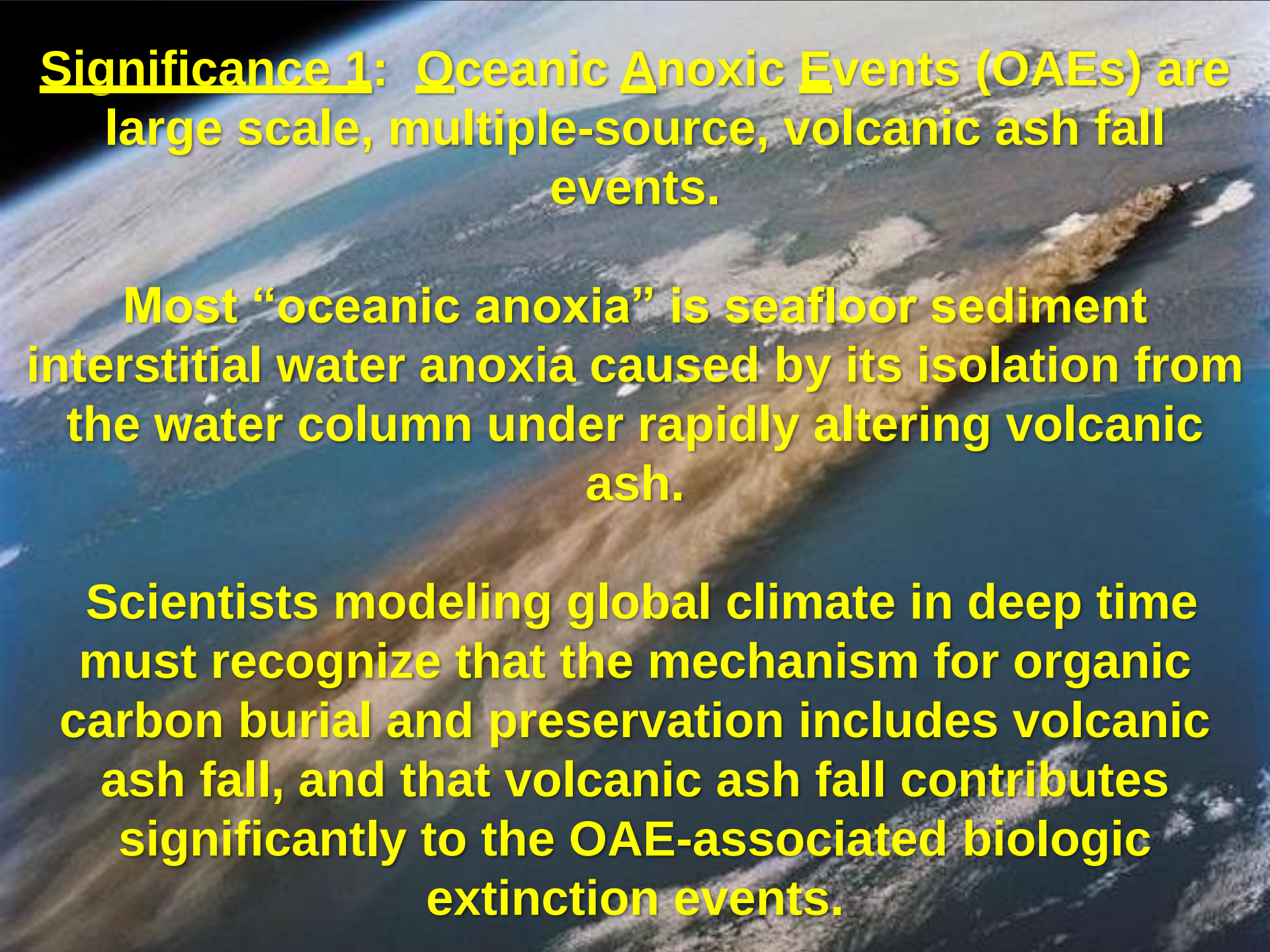


Title: Some geoscientists are concluding that organic enrichment of rock is by volcanic ash fall. The implications are dramatic; but are they probable?

D. M. Parker

Independent Geologist, Highlands Ranch, CO

September, 2019



Significance 1: Oceanic Anoxic Events (OAEs) are large scale, multiple-source, volcanic ash fall events.

Most "oceanic anoxia" is seafloor sediment interstitial water anoxia caused by its isolation from the water column under rapidly altering volcanic ash.

Scientists modeling global climate in deep time must recognize that the mechanism for organic carbon burial and preservation includes volcanic ash fall, and that volcanic ash fall contributes significantly to the OAE-associated biologic extinction events.

Significance 2: Most "redox-sensitive" authigenic minerals in shale are delivered to the sediments by altering volcanic ash, and did not precipitate from the water column under saturation conditions. This includes Uranium, Vanadium, Molybdenum and others.

Volcanic Ash fertilizes primary production of water bodies, descends with and preserves the resulting organics by rapid burial, then alters to release minerals including uranium and potassium. This is why well gamma ray logs frequently track with TOC.

Significance 3: Lagerstatten fossil sites (those sites where soft-body parts are preserved in detail) are the result of Volcanic Ash Fall and its alteration. The mechanism described for the Florissant Fossil Beds of Colorado essentially applies to them all.

Zimmerle (1985) and Parker (2017-RMS-AAPG-Billings, MT) concluded that all organically enriched rocks are the result of volcanogenic input -- both direct ash fall and redeposition of ash fall minerals. Cin-Ty A. Lee et al. (2018) wrote that volcanic ash was a driver of carbon burial in the Cretaceous. Frebourg et al. (2016) examined outcrops of the Boquillas-Eagle Ford and concluded that the cyclicity of organic enrichment, and those nutrients causing organic enrichment, were from volcanic ash fall. Zeng et al. (2018) recognized iron fertilization of primary productivity by volcanic ash in the Cenomanian Western Interior Seaway. Sonnenfeld et al. (2016) found “hundreds” of layers of volcanic ash in the organically enriched Niobrara Formation.

If All organically enriched rocks result from an influx of volcanogenic minerals, what concepts must change in our understanding of sedimentary rocks?

For ash to make organically enriched rocks, at a minimum, these two concepts must also be true:

(1) A direct link must exist between volcanic ash fall and Oceanic Anoxic Events when the majority of organically enriched rocks formed,

(2) Altered ash minerals must make up a very large, mostly unrecognized and unquantified, part of non-organically-enriched sedimentary rocks.

{because ash also fell on dry land, or in environments where it did not fertilize primary productivity}

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Is there a direct link between volcanic ash fall and Oceanic Anoxic Events -- when the majority of organically enriched rocks formed?

The emplacement of Large Igneous Provinces (LIPs) is the recognized “Trigger” for Oceanic Anoxic Events and the Paleocene-Eocene Thermal Maximum (PETM)

PETM	**No. Atl. Ign. Prov.**	**Dickson et al (2015)**
Cret/Pal.	**Deccan Traps**	**V. Courtillot et al (1986)**
Cen/Tur.	**Caribb. LIP/Hi-Arctic LIP**	**C. Shroder-Adams et al (2019)**
Early Aptian	**H.Arctic LIP; Ontong Java Pl.**	**Corfu (2013); Zorina (2017)**
Trias/Juras.	**Central Atl. Magm. Prov.**	**Marzoli et al. (2004)**
Permo-Triassic	**Siberian + Tungass Traps**	**Renne (1995) & Hong (2011)**
Late Dev/Carb.	**Kola & Timon-Pechura magm.**	**Bond-Wignall (2014)**
End Ord.	**Mercury anomalies indicate LIP**	**Sell (2013) Jones (2017)**

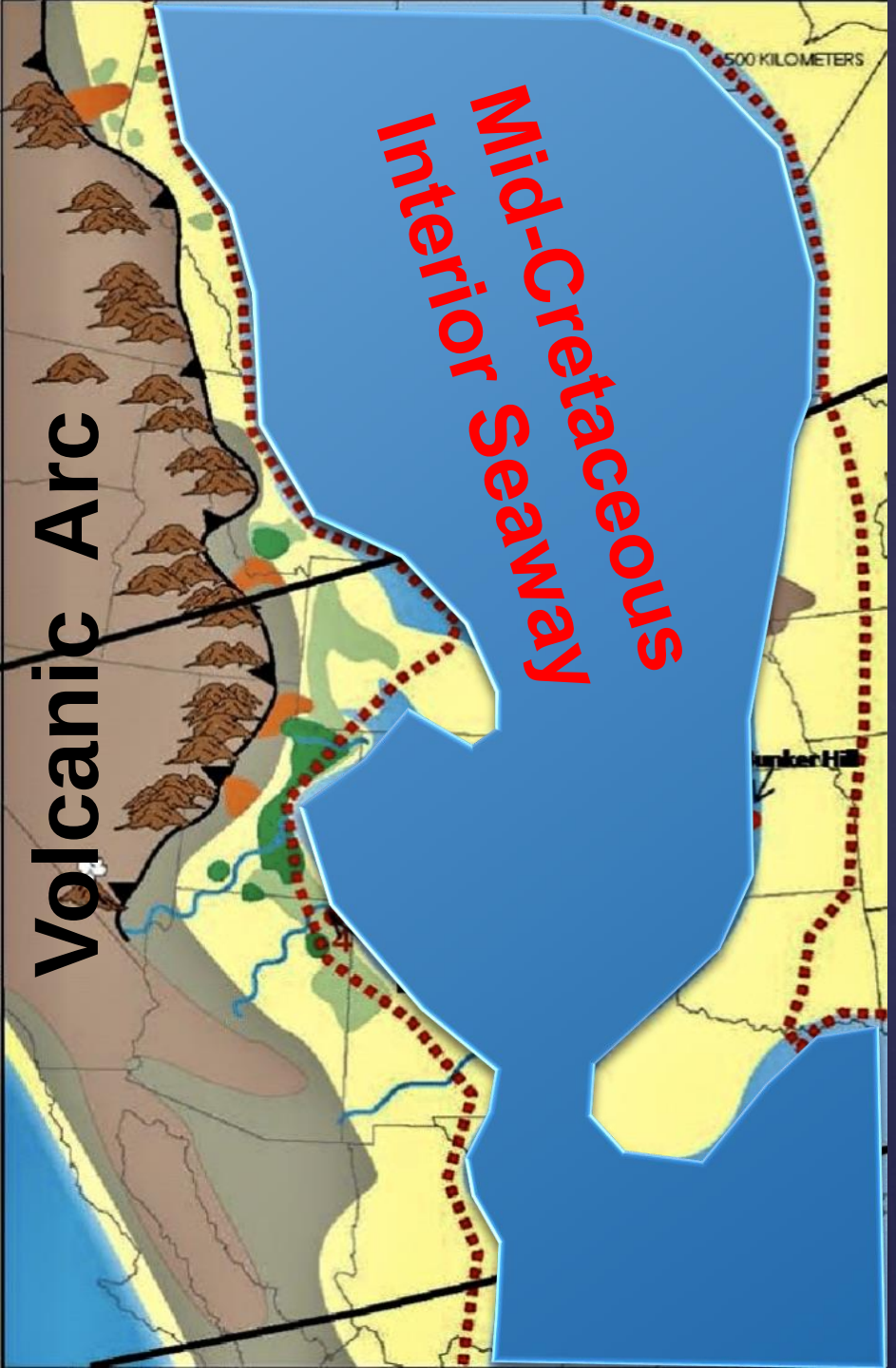
Ross et al. (2005) observed “the near-ubiquitous occurrence of mafic volcaniclastic deposits as an integral component in large igneous provinces.”

“Mafic volcaniclastics make up a significant fraction of large igneous province eruptive volume”.

(E.g. beneath Siberian flood basalts (trigger for late Permian OAE), for 200 km along Angara river visible volcaniclastics 250 m thick; near Tura, Siberia, drill cores show 500 m thick tuffs; more than 300 m. thick in Greenland from PETM – linked NAIP (Ukskins-Peate et al., 2015)

“The volcaniclastics in flood basalts may be the major missing link between flood basalts and extinctions.” (Ukstins Peate et al., 2015)

Established: A direct link between the emplacement of Large Igneous Provinces triggering OAEs and large volumes of Volcanic Ash Fall



In North America, compounding the effects of global LIP volcaniclastics was ash from an active volcanic arc west of the Interior Seaway.

Volcanism extended from Triassic to Late Cretaceous peaking in the Cenomanian (95 Ma) and Campanian-Maastrician boundary (75 Ma) (Christianson et al.,1994). {And episodically through Oligocene}.

Drawing Modified From: Shang, Fei & Chen, Ruiqian & Zhao, Zehui & Scott, Robert & Song, Li. (2018). High-Precision Chronostratigraphic Correlation of Mid-Cretaceous Strata in Western Interior Basin, USA through Graphic Correlation Technique. Journal of Geoscience and Environment Protection. 06. 266-277. 10.4236/gep.2018.65023.

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{ash would also have fallen on dry land, or in environments where it did not fertilize primary productivity}

The complexity of diagenetic alteration of a volcanic tuff can be appreciated in a description of the Mahogany Marker Tuff from the Eocene Green River Shale.

"The Mahogany marker tuff consists of authigenic sodium feldspar, analcime, quartz, ankerite, dolomite, potassium, feldspar, calcite with lesser amounts of siderite, hematite, pyrite, undifferentiated clays, pyrrhotite, biotite, marcasite, and locally dawsonite."

(Glenn Mason, 1983)

Geoscience has not quantified the volumes of volcanogenic feldspar or quartz in sedimentary rock. These minerals are only recognized as volcanogenic because they remain in their original depositional layer.

Volcanogenic minerals “hidden” in plain sight include quartz sand and mud from the Eocene and Miocene of East Java (part of volcanic island arc). “Factors traditionally used to assess the maturity of sediments such as grain size distribution and grain morphology may not be applicable.” (Smyth et al., 2003); chert is from chemical weathering of ash in Permo-Triassic Newcastle coal measures of Sydney Basin, Austrailia (Wadia, 2007; Chatellier, 2015); Clays and insoluble minerals in limestones in SE U.S. clearly reflect volcanic and tectonic activity from Caribbean and G.O.M., including volcanogenic bauxite deposits in limestones of Jamaica; Paleozoic and Mesozoic uplift and orogeny “have left their signature far from the sites where uplift was taking place” (Isphording, 1995).

Hematite in Permo-Carboniferous red beds of SE France is volcanogenic (contain titanium) Kruiver et al., 2000); In the Tethyan Atlantic, Pacific, and Indian Oceans, Cretaceous Oceanic Red Beds (CORBs) had two paleogeographic expansions, (1) shortly after OAE1a (early Aptian ~ 120.5 Ma), and (2) in Turonian after OAE2 (93.5 Ma; Wang, Chengshan et al., 2009)

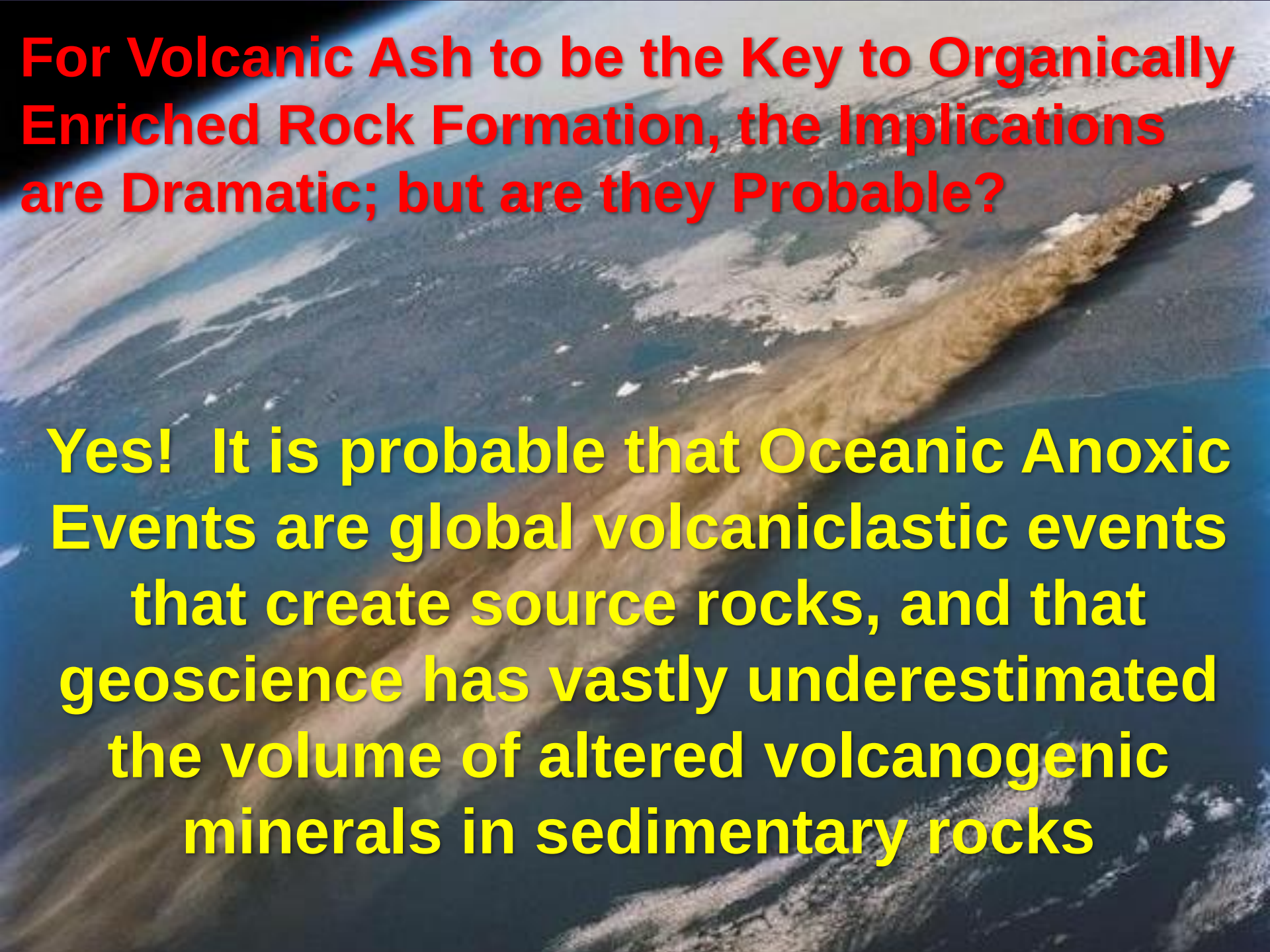
Chamosite in Mid-Ordovician iron-rich oolites formed authigenically from iron minerals when volcanic ash dissolved on the seafloor (Ulf Sturesson, 1992).

Uranium is leached from ash in Jurassic Morrison Formation of New Mexico. "The Uranium is envisioned as forming either essentially on the surface as the sediments were being deposited or at very shallow (20 ft; 6 m) depth" (Falkowski et al. 1979; Dahlkamp, 1993).

Eocene uranium in Gulf Coast sediments is leached from ash (Hall, Susan, 2013).

Trona ($NaCO_3$) of the Green River Shale and in Turkey is an evaporative mineral from ash fall alteration (Turkey -- Helvaci, C., 2010)

Conclusion: Volcanogenic Minerals are emitted in great quantities during LIP emplacement (as well as from coincident arc volcanism) at OAEs and their alteration minerals are much more diverse than just bentonites and tonsteins. These altered minerals have not been quantified in the sedimentary rocks; partly because large volumes have been eroded, re-deposited, and are no longer in layers.



For Volcanic Ash to be the Key to Organically Enriched Rock Formation, the Implications are Dramatic; but are they Probable?

Yes! It is probable that Oceanic Anoxic Events are global volcaniclastic events that create source rocks, and that geoscience has vastly underestimated the volume of altered volcanogenic minerals in sedimentary rocks

Please come and contribute your knowledge to my poster sessions entitled:

Can volcanic tephra-fall replace transgressive seas as an explanation for organically enriched rocks at the Cenomanian/Turonian Boundary (OAE2)?

And

Organically enriched rocks have been causally attributed to transgressive seas largely because of a misunderstanding of the “condensed section” in sequence stratigraphy

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