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Paleo-elevation constraints from a complexly deformed pre-Colorado River geomorphic surface: Significance of carnotite occurrences in the Southern Nevada region

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It's been 100 years (1923) since D. Foster Hewett described sparse occurrences of carnotite, $K_2(UO_2)_2(VO_4)_2 \cdot 3H_2O$, near Goodsprings in southern Nevada. Hewett later (1956) named the associated geomorphic surface the Ivanpah Upland. These near-surface carnotite occurrences and several additional discoveries support the inference of an extensive pre-Colorado-River lowland in the Lake Mead region that can be quantified for modeling and visualization as a very flat parabolic cylinder that has been deformed by recently clarified dynamic processes in Earth's mantle. Shallow groundwater associated with this paleovalley would precipitate carnotite given modest evaporation assuming the starting compositions resembled those in Recent groundwater samples from eastern Las Vegas Valley (Johnson, 1982). A strong pedogenic overprint does not diminish the evidence that phreatic groundwater was responsible for these and other unusual hydroallogenic mineral assemblages (Brock, 2007) in uraniferous calcretes of the region.

There is also carnotite associated with the "fossil water table" of Anderson (1969) streetside in Boulder City, and an occurrence was discovered north of Mesquite in association with a radiometric anomaly near Mormon Mesa, a geomorphic surface equivalent to the Ivanpah Upland that developed unconformably on the Muddy Creek Formation. The Mormon Mesa calcrete was long thought to be pedogenic but the carnotite occurrences investigated in this study indicate otherwise, based on mineralogical field evidence, natural analogues (Yeelirrie, Western Australia) and reaction-path modeling of evaporative solution chemistry and sequential mineral precipitation. These carnotite occurrences offer a powerful tool to constrain the Mio-Pliocene paleo-elevation history of the Lake Mead region, *if the role of groundwater in calcrete development is interpreted correctly*.

A coupled finite-element model of regional groundwater and heat flow describes the present-day southeastern Nevada flow system and provides scaling relations for the larger, late Miocene flow system that was disrupted by crustal movements in the 6-4.4 Ma time frame. Models based on mantle dynamics indicate monotonic subsidence of ~1.5 km in the central-eastern Basin and Range since the middle Miocene, which would have eliminated a huge recharge area in northwestern Utah that is now in its collapsed form the West Desert. Uplift of 550 m of the former discharge environment area in the Lake Mead – Lower Colorado region before 4.4 Ma caused ponding with eventual spillage and consequent erosion as the lower Colorado River as we know it developed. This result begs the question: Can the deformed Ivanpah Upland be recognized in the Ash Meadows / Amargosa Flat area and on the Darwin Plateau and beyond (Jayko, 2009) to reveal differing tectonic modifications of the same Mio-Pliocene land-surface datum?

The Mg-clay beds and surrounding calcite veins at Amargosa Flat are here interpreted to be associated with a remnant of the Ivanpah Upland and owe their origins to evaporation of groundwater discharge, pre-conditioned by dedolomitization of the up-gradient carbonate aquifer that was driven by gypsum dissolution (Back et al., 1983; Plummer et al., 1990). Neglecting matrix diffusion of radiocarbon caused those authors to underestimate flow velocities in the Madison Limestone, however. Dedolomitization offers a thermodynamically rigorous explanation for dissolved Mg enrichment, a key precursor to evaporation-driven palygorskite and sepiolite precipitation in the Amargosa (Birsoy, 2002). Based on the maximum ages of ash beds in Lake Tecopa and occurrence of sepiolite low in the Tecopa lake beds, precipitation of Mg-clays in Amargosa Flat appears to have ended at about the time the spring-fed Amargosa River was born in association with the opening of Death Valley.

Extension east of the Spring Mountains had largely ceased by 6 Ma (Wernicke, 1988) though significant vertical crustal movements persisted. West of the Spring Mountains a record of the transition from Pliocene to Pleistocene hydrogeology is available in the sedimentary record of the Amargosa – Death Valley region, via Mg-clay and borate accumulations on opposite sides of the Furnace Creek Fault Zone followed by Lake Tecopa sedimentation. The proposal here is that the vestigial northeastern system was split in response to Pleistocene extension of the Death Valley – Darwin Plateau region to discharge in part (as it does today) to the Death Valley segment of the collapsing Eastern California Shear Zone, and in part to warm springs in eastern and southeastern Nevada. The western (?) system responsible for borates in the Funeral Mountains has been so disrupted by complex faulting between Death Valley and the Sierra Nevada that the recharge area and groundwater flow paths to the borate beds remain indeterminate though ripe for paleohydrologic evaluation.

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1. Typical carnotite occurrence from the Hidden Valley calcrete, and the original discovery location in railroad cuts near Erie
2. Hewett's source publication from 1923 and his original map are shown here
3. The carnotite occurrences near Goodsprings conform to an east-sloping surface
4. Cima Dome from the ground and an overview of the Ivanpah Upland looking north toward Pahrump (upper left) and Boulder City (upper right)
5. Exposed patches of the erosional surface mapped by Jayko are shown here
6. This paleohydrologic feature, characterized primarily by Mn-oxide staining, clearly pre-dates the Colorado river in this area; note Hoover Dam in lower right
7. Anderson's control points are shown here
8. The fossil water table slopes gently to the east in this area
9. This map shows carnotite occurrences known in 1982
10. We can't just wave our arms, we need to quantify our ideas for meaningful discussion; keep this conceptual paleovalley in mind as the basis of a key finding
11. The mineralogy of the calcrete has much to offer that was apparently unknown to these authors
12. The view here is northeastward toward the Beaver Dam Mountains; note the channeling along strike of the bedding
13. The top of this spring mound in California Wash Basin is part of the east-dipping accrete surface; If you can't see clear evidence of groundwater discharge here you have no soul!
14. There's no way to produce the observed mineral assemblage from the rain! Gypsum is a key contributor to mineral paragenesis.
15. Hadn't Longwell's "Lake Las Vegas", like Swadley and Carr's "Lake Amargosa" been put to rest decades ago?
16. An NTS-centric model is not helpful in the present analysis, and more generally, has likely outlived its useful life
17. We should all understand DOE's Licensing-directed motives and strategy for model development, but there are serious conceptual flaws that beg the question WHY apply it outside the Licensing arena?
18. Heat lost from the Eureka Low, perhaps the best natural tracer out there, and recharge from snowpack in the high country of east-central Nevada, are conspicuously absent from the formulation of the DVRFS model
19. There is no obvious reason the anisotropy field needs improvement, but revision of the Eureka Low westward should be the first calibration adjustment
20. The distribution of heat input from the Eureka Low will require revision to produce warmer groundwater temperatures in the Amargosa region of the model domain
21. Just as the Colorado Plateau is not high enough today and was certainly not high enough at 6 Ma to produce significant recharge, the Spring Mountains are a tiny speck in the regional recharge domain and separated from the Tecopa area by the State Line Fault
22. Is there evidence the West Desert of Utah between the Snake Range and the Wasatch Plateau was once at similar elevations to those areas?
23. As it turns out, the answer is yes, based on seismic tomography
24. The Pavlis analysis indicates an important and persistent tectonic boundary roughly coincident with the Kings Canyon Lineament of Troutman (1979)

25. Deeply-sourced fluids have found expression south of the slab-window edge in post-Miocene time
26. Today we have a number of large, tilted blocks that preserve near-planar remnants of the Ivanpah Upland surface. The California Wash surface was shown in an earlier slide, and Las Vegas Valley is underlain by a nearly planar, east-dipping calcrete surface encroached upon by 3 large but younger alluvial fans
27. This finding offers an explanation for the birth of the lower Colorado River that satisfies the “Muddy Creek Constraint”
28. For emphasis, the anisotropy ellipse of Ferrill is shown again here, strike-parallel to the Pliocene potentiometric surface of Amargosa Flat
29. Is the absence of GPS data from the NTS evidence of scientific malpractice by DOE, or just lack of access for academic researchers? This would not be the first such complaint.
30. The juxtaposition here is striking, but note post-depositional right-slip on the Furnace Creek Fault Zone must be restored for proper consideration of the paleohydrology
31. There is a sigh-up sheet for copies of this presentation and a reference list; the .pdf file is about 13 Mb
32. Adam, this one’s for you!