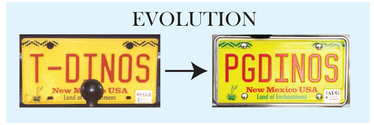


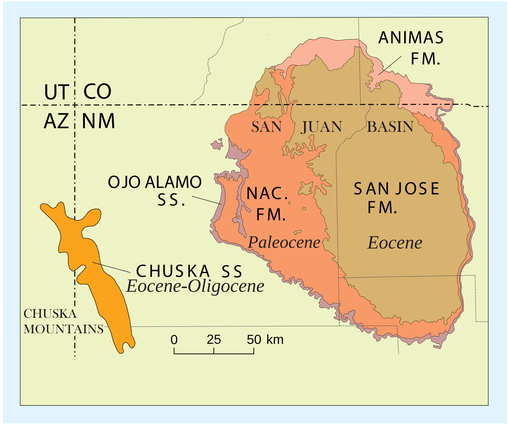
^{40}AR/^{39}AR SANIDINE AGES CONFIRM THE ~250 KY-DURATION OF DEPOSITION OF THE PALEOCENE, DINOSAUR-BEARING, OJO ALAMO SANDSTONE IN THE SOUTHERN SAN JUAN BASIN, NEW MEXICO

JAMES E. FASSETT, USGS (Retired), Independent Research Geologist
Santa Fe, NM, *jimgeology@aol.com*

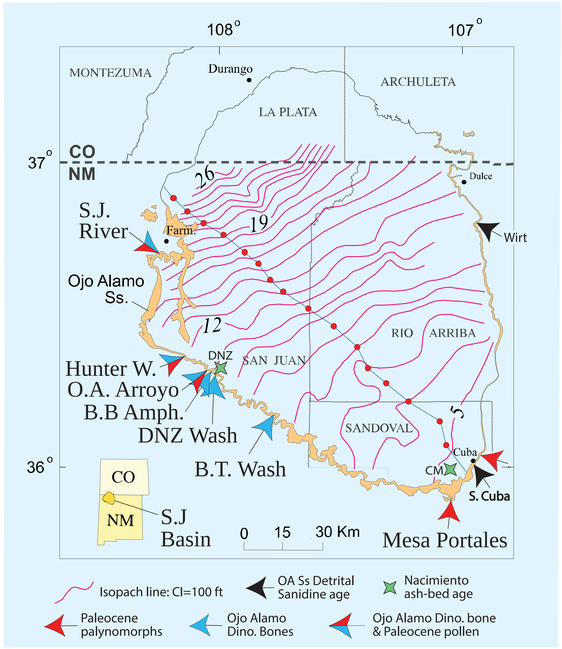
The author with Paleocene dinosaur bone from SJ River locality.

ABSTRACT

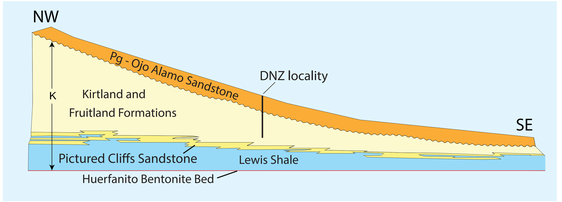
The Ojo Alamo Sandstone of the San Juan Basin, New Mexico and Colorado, is early Paleocene in age in its entirety throughout the basin based on contained palynologic data from numerous localities. The Ojo Alamo also contains abundant dinosaur fossils found in multiple localities in the basin. Conclusive evidence shows that these dinosaur bones have not been reworked and were fossilized in place in the Ojo Alamo Sandstone as evidenced by trace-element geochemistry of large suites of these fossil bones. An earlier report, based on existing ^{40}Ar/^{39}Ar sanidine ages bracketing the Ojo Alamo, suggested that it was deposited from between about 65.95 Ma and 65.70 Ma or over about 250 ky in the southern San Juan Basin. (The Ojo Alamo Sandstone is on the order of 25-30 m thick in that area; the Ojo Alamo ranges in thickness up to 130 m in places in the northern part of the basin and in those areas its depositional interval could represent as much as one million years.) The previously reported age for the top of the Ojo Alamo was based on a ^{40}Ar/^{39}Ar sanidine age of 65.7 Ma age for an altered volcanic ash bed from the lower part of the overlying Nacimiento Formation, however the distance above the top of the Ojo Alamo Sandstone was not known at that time. It is now known that this ash bed has an age of 65.5 Ma and that the dated ash bed is 10.5 m [revised from 13 m in original abstract] above the top of the Ojo Alamo. Because the rate of deposition of the lowermost Nacimiento Formation in the southern San Juan Basin is about 53 [revised] m/my, the top of the Ojo Alamo must be about 65.7 Ma based on the more precise data discussed above. Thus the previous determination of the time represented by Ojo Alamo Sandstone deposition in the southern San Juan Basin of about a quarter-million years has now been confirmed by more precise data. However, in those parts of the basin where the Ojo Alamo is thicker, the time interval for its deposition would have probably been proportionally greater and its upper boundary would be commensurately younger. A published U/Pb age for a dinosaur bone from the lower part of the Ojo Alamo Sandstone of 64.8±0.9 m.y. would have a maximum uncertainty age of 65.7 Ma and is thus too young – dinosaur bones in the lower part of the Ojo Alamo must be on the order of 65.9 Ma, based on the available data discussed above.



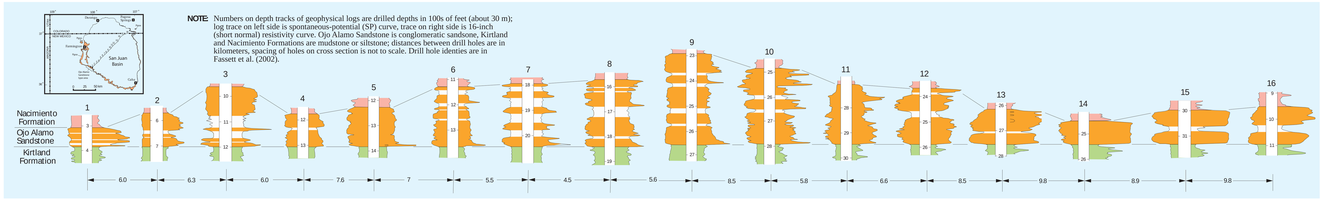
Geologic map showing outcrops of Paleogene rocks in northwest New Mexico, southwest Colorado, and northeast Arizona. Modified from Fassett, et al. (2010).



Index map of San Juan Basin showing important data localities. Red northeast-trending isopach lines show thickness of the Cretaceous interval (shown below) between the base of the Paleocene Ojo Alamo Sandstone and the Huerfanito Bentonite Bed of the Lewis Shale. Well log cross section below is along line of section shown on map. Modified from Figure A3-3 of Fassett (2000).



Southeast-trending stratigraphic cross section showing truncation of Cretaceous Kirtland and Fruitland Formations resulting from erosion of those rocks prior to deposition of the Paleocene Ojo Alamo Sandstone. Datum is Huerfanito Bentonite Bed of Lewis Shale. A 7.6 m.y. unconformity is present at the base of the Ojo Alamo Sandstone at the DNZ Wash locality (see index map above); this hiatus ranges from ~ 4.4 m.y. in the NW to ~8.9 m.y. in the SE (Based on rates of deposition for the Cretaceous interval shown of 141 m/m.y. (Fig. 17A of Fassett, 2000). Modified from Figure A3-3 of Fassett (2000).



Geophysical drill-hole-log cross section showing Ojo Alamo Sandstone trending northeast across the subsurface of the San Juan Basin, trace of cross section shown on basin index map. Modified from Fassett, et al. (2002).

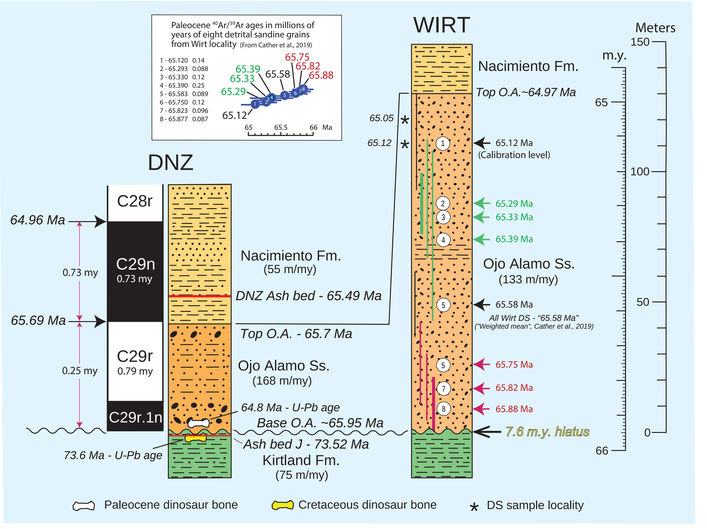
^{40}AR/^{39}AR SANIDINE AGES

All of the ^{40}Ar/^{39}Ar sanidine age determinations discussed herein were made by Matthew T. Heizler at the N.M. Tech geochronology lab in Socorro, N.M.

The four localities where samples were collected for ^{40}Ar/^{39}Ar sanidine age determinations discussed herein are shown on the adjacent San Juan Basin index map. The two samples collected from the Nacimiento Formation came from altered volcanic ash beds whereas the two Ojo Alamo Sandstone samples were collected to date detrital sanidine grains from within the Ojo Alamo. Sanidine ages from altered volanic ash beds directly date the age of the ash bed and adjacent strata whereas ages obtained for detrital sanidine grains only provide a maximum (open ended) age for the sampled rock unit. Thus, a sampled bed could be younger, but never older, than the dated sanidine grains within it. Supporting evidence, such as paleomagnetic data, for the age of rocks determined by detrital-sanidene dating, must be present to validate detrital-sanidine dating.

Paleomagnetic surveys have been made through the Ojo Alamo Sandstone (and underlying, and overlying rocks) in the southern San Juan Basin (Lindsay et al., 1981, Fassett, 2009). The paleomagnetic reversal C29r-C29n, is located at or near the top of the Ojo Alamo at the DNZ Wash and B.T. Wash localities (see adjacent map and stratigraphic column). The age of this reversal is 65.69 Ma (Gradstein et al., 2012); top of Ojo Alamo is estimated to be 65.7 Ma as shown on DNZ column. Detrital sandine from the top of the Ojo Alamo Sandstone at the S. Cuba site is 65.70 Ma, essentially identical to its paleomagnetic age and the age of the top of the Ojo Alamo Sanstone at the DNZ locality.

The CM volcanic ash bed west of Cuba, NM (see adjacent map) is in the Nacimiento Formation near the tip of Mesa de Cuba (thus its CM designation). This 64.63 Ma ash bed (Fassett, 2013) is 64 m above the top of the Ojo Alamo Sandstone at this locality. The deposition rate for the lower Nacimiento Formation at this locality is ~60 m/my, thus the top of the Ojo Alamo here is ~65.73 Ma validating the detrital sanidine age of 65.70 at the S. Cuba locality.



Stratigraphic and paleomagnetic columns at two localities in the San Juan Basin. Localities are shown on the index map. Paleomagnetic colum is from Lindsay et al. (1980). The DNZ ^{40}Ar/^{39}Ar sanidine age for an altered volcanic ash bed 10.5 m above the top of the Ojo Alamo Sandstone was reported to be 65.7 Ma in Mason et al. (2013), however this age was updated to 65.50 Ma in Cather et al. (2019). Ages of samples from the Wirt locality are ^{40}Ar/^{39}Ar detrital, single-crystal sanidine (DS) ages (Cather, et al. 2019). DS ages are maximum (open ended) ages for samples analyzed and can be younger than ages shown. Ages for top and base of chron C29n are from Gradstein et al. (2012). The ^{40}Ar/^{39}Ar sanidine age for ash bed J is from Fassett and Heizler (2017). The two U-Pb ages for Cretaceous and Paleocene dinosaur bones in the DNZcolumn are from Fassett, et al. (2011). The U-Pb and ^{40}Ar/^{39}Ar sanidine ages for the Cretaceous dinosaur bone are virutally identical validating the value of U-Pb direct-dating of dinosaur bone. The Fassett et al. (2011) U-Pb age determination for this dinosaur bone is the first time the age of a dinosaur bone has been successfully determined using U-Pb dating. The age determination for the Paleocene dinosaur bone, however, was not as successful: as seen on the DNZ column, the base of the Ojo Alamo Sandstone is ~65.95 Ma whereas the dated dinosaur bone U-Pb age is 64.8 Ma, 1.15 m.y. younger and outside of the uncertainty range of /- 0.9 m.y. reported for this age in Fassett et al. (2011). Work is ongoing to resolve this age discrepancy.

REFERENCES

Cather, S.M., Heizler, M.T., and Williamson, T.E., 2019, Detrital sanidine and paleocurrent constraints on deposition of the Paleocene Nacimiento and Animas Formations, San Juan Basin, New Mexico: Geosphere, vol. 15, 24 p.

Fassett, J.E. 2000, Geology and coal resources of the Upper Cretaceous Fruitland Formation, San Juan Basin, New Mexico and Colorado, *in* Kirschbaum, M.A., Roberts, L.N.R., and Biewick, L.R.H., (eds.), Geologic assessment of coal in the Colorado Plateau: Arizona, Colorado, New Mexico, and Utah: USGS Professional Paper 1625-B, Chapter Q (CD-ROM).

Fassett, J.E., 2009, New geochronologic and stratigraphic evidence confirms the Paleocene age of the dinosaur-bearing Ojo Alamo Sandstone and Animas Formation in the San Juan Basin, New Mexico and Colorado: Paleontologia Electronica, v. 12, no. 1, 146 p. (on-line pub. at http://palaeoelectronica.org/splash/index12_1.html).

Fassett, J.E., Heizler, M.T., and McIntosh, W.C., 2010, Geologic implications of an ^{40}Ar/^{39}Ar single-crystal sandine age for an altered volcanic ash bed in the Paleocene Nacimiento Formation in the southern San Juan Basin, New Mexico, *in* Fassett, J.E., and Ziegler, K.T., eds., Geology of the Four Corners Country: New Mexico Geological Society 61st Annual Fall Field Conference Guidebook, p. 147-156.

Fassett, J.E., 2013, Revised geogchronology and paleomagnetic interpretations of uppermost Cretaceous and lowermost Paleocene rocks in the southern San Juan Basin, New Mexico, *in* Ziegler, K.; Timmons, J.M.; Timmons, S.T.; and Semken, S. (eds.), Geology of Route 66 region: Flagstaff to Grants: New Mexico Geological Society 64th Annual Fall Field Conference Guidebook, p. 215-222.

Fassett, J.E., Heaman, L.M., and Simonetti, A., 2011, Direct U-Pb dating of Cretaceous and Paleocene dinosaur bones, San Juan Basin, New Mexico: Geology, v. 39, p. 159-162.

J.E. Fassett and M.T. Heizler, 2017, An improved new age for the C33n-C32r paleomagnetic reversal, San Juan Basin, NW New Mexico and SW Colorado, *in* Karlstrom, Karl E.; Gonzales, David A.; Zimmerer, Matthew J.; Heizler, Matthew; Ulmer-Scholle, Dana S., (eds.),The Geology of the Ouray-Silverton Area: New Mexico Geological Society 68th Annual Fall Field Conference Guidebook, p. 115-121.

Fassett, J.E., Zielinski, R.A., and Budahn, J.R. 2002, Dinosaurs that did not die: Evidence for Paleocene dinosaurs in the Ojo Alamo Sandstone, San Juan Basin, New Mexico,*in* Koerble, C. and McLeod, K.G. (eds.), Catastrophic Events and Mass Extinctions: Impacts and Beyond: GSA Special Paper 356, p. 307-336.

Gradstein, F.M., Ogg, J.G., Schmitz, M.D., and Ogg, G.M., 2012, The Geologic Time Scale 2012: Amsterdam, Elsevier, 2 volumes, 1144 p.

Lindsay, E.H., Butler, R.F., and Johnson, N.M. 1980, Magnetic polarity zonation and biostratigraphy of Late Cretaceous and Paleocene continental deposits, San Juan Basin, New Mexico: American Journal of Science, 281:390-435.

Mason, I.P., Heizler, M.T., and Williamson, T.E., 2013, ^{40}Ar-^{39}Ar sanidine chronostratigraphy of K-Pg boundary sediments of the San Juan Basin, NM (abs.): New Mexico Geological Society 2013 Spring Meeting Proceedings.