LATE DEVONIAN ALAMO EVENT, NEVADA, USA; MULTIPLE EVIDENCE OF AN OFF-PLATFORM MARINE IMPACT. J. R. Morrow[1] and C. A. Sandberg[2], [1]Department of Earth Sciences, University of Northern Colorado, Greeley, CO 80639, USA, jared.morrow@unco.edu, [2]Geologist Emeritus, U.S. Geological Survey, Box 25046, MS 939, Federal Center, Denver, CO 80225, USA, sandberg@usgs.gov.

Introduction: The early Late Devonian (early Frasnian) Alamo Event is proven to have resulted from a marine impact [1–3] into interbedded carbonate and siliciclastic target strata offshore from the carbonate-platform margin [4, 5]. Post-Event geologic processes along the tectonically active western North American continental margin, however, have dismembered and buried the 1.5-km-deep, 50- to 75-km-wide crater. Allochthonous and semi-autochthonous polymict breccias, impact ejecta, and seismically disturbed strata resulting from the impact are now exposed in more than 20 mountain ranges in southern and central Nevada and western Utah, USA (Fig. 1). Megabreccia and tsunamite deposits were emplaced in: (a) roughly semicircular, shoreward-thinning belts, designated Zones 1, 2, and 3, across the carbonate platform and adjacent ramp; (b) localized, erosive, crater-fill channel or sheet deposits that downcut into deep-water ramp and slope strata as old as Middle Devonian (e.g., MLK, RMW, SKR, and CW, Fig. 1); and (c) distal, fine-grained, possible uprush-related channels on the inner carbonate platform (e.g., DVG, Fig. 1).

Impact-Related Phenomena: Since recognition of the impact origin for the Alamo Breccia and related Event deposits [1-3], there has been a growing body of evidence documenting the magnitude, paleogeographic setting, chronology, and distal effects of the impact. At present, in the absence of a preserved crater, at least 15 separate lines of geologic, petrographic, and geochemical evidence demonstrate that the Alamo Event was caused by a relatively large cometary impact into a deep-water, off-platform marine setting. Existing evidence further demonstrates that the ensuing target vaporization, platform collapse, transient-crater modification, megatsunami, and ejecta emplacement followed a complex, multi-stage evolution. Important lines of evidence documenting an impact genesis for the Alamo Event include:

(1) Megabreccia – Size, location, and distribution of radially imbricated blocks and megablocks in Zone 2 and in offshore, deep-water channel deposits of the Alamo Breccia [1, 3, 4, 6].

(2) Clastic dikes and sills – Extending at least 300 m stratigraphically beneath the Breccia; provided conduits for mobilization and upward injection of quartz sand grains from underlying partly consolidated siliciclastic strata [1-4].

(3) Lateral shock waves – Detachment surfaces beneath semi-autochthonous, platform megabreccia blocks in Zone 2 [1-3], disruption and plastic deformation of sub-Breccia units in Zone 1 [1, 3], and probable seismites in the distal platform setting where the Breccia is absent [4].

(4) Megatsunami deposits – Multiple, stacked event beds capping the Breccia in Zone 2 and in offshore channels [1-3], stranded uprush deposits in Zone 3 [1-3], and possible distal uprush channels [2, 4].

(5) Iridium anomaly – High relative abundance above background levels, but low absolute concentration (average value ~70 ppt) [3, 7], suggesting a probable cometary impactor.

(6) Shocked quartz grains – Abundant within onshore and offshore deposits of the Breccia, sub-Breccia clastic dikes and sills, and carbonate accretionary lapilli; showing Planar Deformation Feature (PDF) distribution and orientation diagnostic of sedimentary target shock metamorphism [1, 3, 5, 7-9].

(7) Ejected, redeposited conodont microfossils – Within the upper part of the Breccia, occurring in association with carbonate accretionary lapilli and other ejecta fragments; indicating that crater excavation penetrated deep into Lower Ordovician strata 1.5 km beneath the early Late Devonian seafloor [1, 2, 4, 5].

(8) Carbonate accretionary lapilli – Impact-fallout spherules, produced by condensation of vaporized carbonate rock, which occur in the upper part of the Breccia as isolated grains and in normally graded blocks that had been partly cemented shortly after deposition; subsequent megatsunami fragmented, reworked, and redeposited the lapilli beds as blocks [3, 7].

(9) Ejecta bomb – Spindle-shaped, zoned impact-fallout projectile within an offshore Breccia channel at Milk Spring (MLK, Fig. 1), showing evidence of a complex accretional history during ballistic aerial transport [10].

(10) Distal ejecta – Isolated occurrences of inclusion-rich quartz grains containing abundant planar fractures and rare PDFs at a stratigraphic level correlative with the Alamo Event, but where the Alamo Breccia may not have been deposited or preserved (e.g., NAR and CON, Fig. 1) [5, 9, 10].

(11) Glassy melt grains – Isolated within the Breccia matrix and occurring within the ejecta bomb are cryptocrystalline, partially isotropic spherical and aggregate grains, which may represent original silicate melt ejecta [10].

(12) High-pressure quartz polymorphs – Small, optically high-relief crystals are a common feature within highly decorated, mono- and poly-crystalline Alamo shocked quartz grains; although not yet confirmed by other quantitative methods, these crystals may be the high-pressure quartz polymorph coesite.

Conclusions: Given the high probability that craters from pre-Pangea oceanic impacts may not be preserved in the geologic record, other converging lines of evidence, such as those documented for the Alamo Event, must be used to recognize and correctly catalogue ancient marine impacts.

Evidence compiled for the Alamo Impact documents the great magnitude and wide extent of the Event within onshore, offshore, and distal settings. Resulting breccias are now recognized at least 100 km from the inferred impact site, and distal quartz ejecta, as distant as 250 km. We interpret offshore deposits of the Alamo Breccia to be large, submarine mass-flow channels or sheets that were emplaced both by high-energy, outward- and downslope-directed surge currents/tsunami originating at the Alamo Impact site and by inward-directed return currents backfilling the unstable transient crater. The complex internal stratigraphy of both onshore and offshore Breccia indicates that post-impact platform collapse, submarine mass-flow, and resulting megatsunami may have played an important role in modifying the initial Event deposits. On the basis of the multiple lines of evidence now recorded, we conclude that the Alamo Event resulted from a relatively large (~5-km-diameter) cometary impact into a deep-water, oceanic target west of the early Late Devonian carbonate platform.

Acknowledgments: J.E. Warme, A.C. Chamberlain, H.-C. Kuehner, F.G. Poole, and W. Ziegler are gratefully acknowledged for their contributions to our expanding knowledge and understanding of the Alamo Event.

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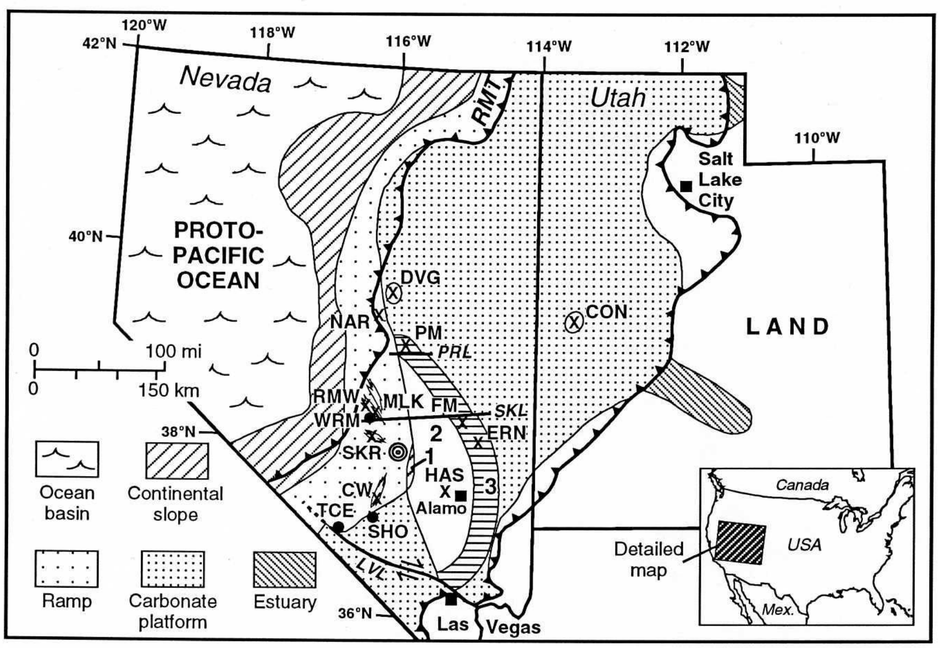

Figure 1 – Paleotectonic map (partly restored) of Nevada and Utah during early Frasnian *punctata* Zone, showing possible site of oceanic Alamo Impact (bullseye) relative to carbonate platform and distribution of resulting Alamo Breccia and related deposits. Alamo Breccia Zones 1, 2, and 3 form semicircular pattern on ramp (Zone 1), outer carbonate platform (Zone 2), and peritidal, inner platform (Zone 3). Also shows location of four deep-water channels of Alamo Breccia, some representing crater fill and some transporting breccia debris seaward. Selected major post-breccia structural features: ***RMT***, latest Devonian to Early Carboniferous Roberts Mountains thrust, which significantly displaced transitional- and oceanic-facies Devonian rocks; and three Tertiary lineaments that affected distribution of Alamo Breccia – ***LVL***, Las Vegas lineament; ***SKL***, Silver King lineament; and ***PRL***, Pancake Range lineament. Important measured sections: **CON**, Little Mile-and-a-Half Canyon; **CW**, Carbonate Wash; **DVG**, Devils Gate; **ERN**, East Ridge North; **FM**, Fox Mountain; **HAS**, Hancock Summit (type locality of Alamo Breccia); **MLK**, Milk Spring; **NAR**, Northern Antelope Range; **PM**, Portuguese Mountain; **RMW**, Rawhide Mountain West; **SHO**, Shoshone Mountain; **SKR**, Streuben Knob; **TCE**, Tarantula Canyon East; **WRM**, Warm Springs. Alamo Breccia localities are indicated by X's; other important localities are indicated by dots. DVG and CON deposits are unclassified. Modified from [5].