$^{40}Ar/^{39}Ar$ dating of langbeinite [$K_2Mg_2(SO_4)_3$] in late Permian evaporites of the Salado Formation, Southeastern New Mexico, USA

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Late Permian stratigraphy of the southwestern United States reveals an overall shoaling trend between the Guadelupian Stage and the end of the Permian. The shoaling sequence features an upsection progression between marine carbonates, evaporates, and terrestrial red-beds. The virtual absence of fauna in the evaporates and red-beds, which define the Ochoan Series, precludes biostratigraphic age assignment. Thus the duration of the shoaling sequence, and correlation with the global Late Permian record of events is problematic.

$^{40}Ar/^{39}Ar$ (sanidine) dates for tuffs in red-beds of the Quartermaster Fm., at the top of the Ochoan Series in west Texas, bracket the 250.0 Ma $^{40}Ar/^{39}Ar$ age determined for the Permian/Triassic boundary at the Meishan section in south China (Renne *et al.*, 1995). In an effort to extend the geochronological framework downsection, we have undertaken $^{40}Ar/^{39}Ar$ analysis of K-rich evaporate minerals from the Salado Formation.

The Salado Formation comprises *c.* 600–700 m of hypersaline evaporites whose top lies *c.* 100 m below the Quartermaster Fm. through much of west Texas and southeastern New Mexico (e.g. Lowenstein, 1988). Nine horizons of K-rich bittern salts occurring in the McNutt Potash Zone of the Salado Fm. are mined for potash, and commonly contain the mineral langbeinite whose composition is K2M92(S04)3. Langbeinite in other occurrences has been dated by K-Ar (e.g. Pilot and Blank, 1967) and $^{40}Ar/^{39}Ar$ methods (Lippolt and Oesterle, 1977; Lippolt *et al.*, 1993), and in some cases yielded stratigraphically plausible ages.

A sample from the IMC Kalium mine (500 foot level, near the top of the Salado Formation) near Carlsbad N. M. was analysed by incremental heating in a resistance furnace in two experiments. Both samples were about 3 mg single crystals of transparent, highly lustrous langbeinite wrapped in Cu foil. Temperature steps ranged from 450 to 1300°C, and were of 600 s and 1800 s duration in the first (IMC-1.1) and second (IMC-1.2) experiments, respectively.

Gas release was relatively sluggish up to near the melting temperature, at *c.* 880°C. Based on linear Arrhenius relations (assuming spherical diffusion geometry for this isometric mineral), $^{39}Ar_K$ release over the temperature range 600 to 850°C *in vacuo* appears to occur by volume diffusion, with activation energies of 42.7 $\pm$ 5.7 and 42.6 $\pm$ 1.9 kcal/mol. These results are indistinguishable from the activation energy of 44 kcal/mol determined by Lippolt and Oesterle (1977) for $^{40}Ar^*$ diffusion in two different langbeinite samples, and confirm their conclusion that langbeinite is highly argonretentive.

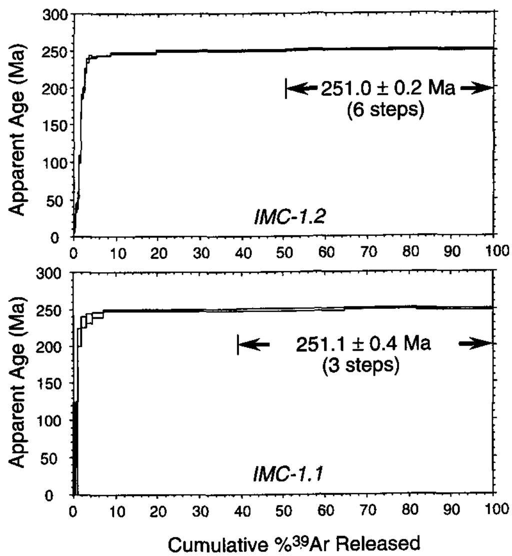

FIG. 1. Apparent age spectra from replicate analyses of upper Salado Fm. Langbeinite.

Both age spectra (Fig. 1) show pronounced low-temperature discordance at less than ~10% $^{39}Ar_K$ released, then rise gently to plateaux over the final 50–60% of the $^{39}Ar_K$ released. The pattern of discordance suggests recent surficial $^{40}Ar^*$ loss, perhaps even during sample preparation and/or irradiation. The plateau ages are 251.0 $\pm$ 0.2 Ma and 251.1 $\pm$ 0.4 Ma, (1σ errors neglecting systematic errors from decay constants, standards, etc.) relative to Fish Canyon sanidine at 28.02 Ma (Renne *et al.*, 1998).

The weighted mean age of 251.0 $\pm$ 0.2 Ma (internal. precision) is consistent with all existing chronostratigraphic data, and at face value supports the possibility that the duration of the Late Permian was substantially shorter than previously believed. Questions remain, however, as to whether langbeinite precipitation occurred during evaporate deposition or during later diagenesis. Existing constraints on the age of the Salado Formation support previous conclusions (Lippolt *et al.*, 1993) that if langbeinite is diagenetic, the diagenesis can occur very close to the age of deposition. Additional studies in progress, on langbeinite from different stratigraphic positions in the Salado Formation, is aimed at clarifying these questions. In any case, our data indicate that the Ochoan Series, and the shoaling sequence represented therein, lasted at least 1.0 $\pm$ 0.5 m.y.

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