Stratigraphy of the Fra Mauro Formation defined by U-Pb zircon ages of breccia samples from Apollo 14 landing site. R. E. Merle[1], A. A. Nemchin[1], M. L. Grange[1], M. J. Whitehouse[2]; [1]Department of Applied Geology, Curtin University, Australia; [2]Swedish Museum of Natural History, Stockholm, Sweden.

Introduction:The Fra Mauro Formation sampled at the Apollo 14 landing site has been interpreted as representing Imbrium impact ejecta. It was excavated by the Cone Crater [1], which has distributed Fra Mauro Formation material from depths of 30-35 meters over a significant area within the landing site. Mineralogical and textural studies of breccias from outside and inside the Cone Crater ejecta blanket suggest that the former originated from a shallower layer within the Fra Mauro formation located underneath the regolith (“subregolith basement breccia”, [2]) while the latter collected near the rim of Cone Crater represent a deeper stratigraphic unit (“Cone crater basement”, [2]) possibly pre-dating Imbrium impact or incorporating older local material. The occurrence of zircons in these breccias opens an opportunity to investigate the provenance of these grains and assess the homogeneity of the Fra Mauro formation. This contribution aims to compare U-Pb age distribution patterns from different breccia types proposed to originate from different depths within the Cone crater to determine whether these breccias can represent similar source rocks within the Imbrium target or require completely different origin, perhaps even as a result of different impact events.

Results: U-Pb dating work was performed using a high-resoltion ion microprobe (Shrimp II and CAMECA ims1280) at Curtin University and at the Nordsim facility in Stockholm.

The studied breccia samples include: (i) 14311 showing an exposure age significantly older than the estimated age of the Cone crater [3,4] and therefore considered to represent the shallow “subregolith basement breccia”, [2]; (ii) breccias collected near the rim of the Cone crater and interpreted to represent the deepest stratigraphic levels within the Fra Mauro formation sampled by the Apollo 14 mission (refered to as the eastern group of samples) and (iii) samples representing the distal part of the Cone crater ejecta western group of samples) and probably coming from intermediate depths within the formation

The analyzed zircon crystals occur in the breccia samples as either separate crystals and fragments scattered in the matrix or included in lithic clasts of variable size. Theses crystals are usually smaller than 100 µm in length and do not show any textural evidence of crystallisation from the impact melt that consolidated the sample. Consequently they all are interpreted as crystals or fragments predating breccia formation.

Although all age distribution patterns appear to show similar major age groups (older than 4.3 Ga, between 4.25 and 4.2 Ga and between 4.1 and 3.9 Ga), there are also some significant differences between the populations (Fig. 1).

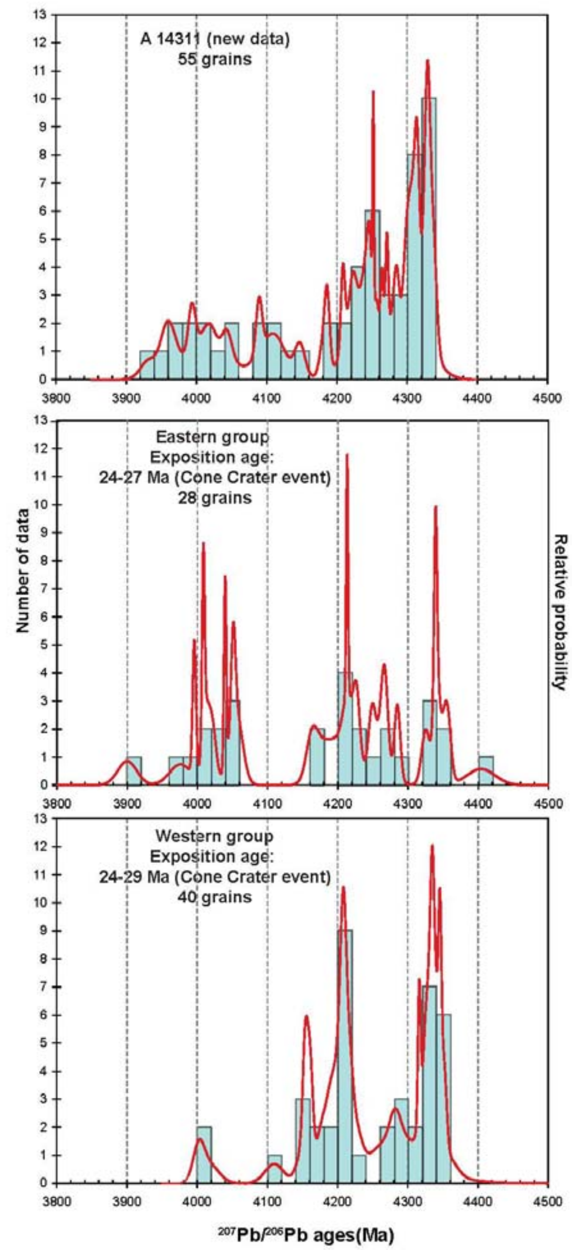

Figure 1: Probability density distribution diagrams of $^{207}Pb/^{206}Pb$ ages of zircon grains from the different types of studied brecca samples

These differences include: (i) markedly different proportions of zircon grains in different age groups (e.g. >4.3 Ga grains are dominant in the sample 14311, while ~4.2 Ga grains are more abundant in samples representing Cone crater ejecta); (ii) slight but significant differences between the ages of grains representing two older groups in 14311and other samples: e.g. >4.3 Ga grains in the sample 14311 are generally younger and centered around 4320-4330 Ma, while in other samples majority of ages are closer to 4350 Ma; similarly slight age differences can be identified for the 4.25-4.2 Ga group of zircons; (iii) only two zircon grains about 4.0 Ga are found to be in the 4.1 and 3.9 Ga age group in the samples representing distal ejecta from the Cone crater. While none of the younger zircons have been found in these breccias they are present in 14311 and the eastern group of samples (Fig. 1).

Additional comparison between the different types of breccias can be made using the youngest grains identified in the samples, which define the maximum deposition age for the relevant stratigraphic unit. These youngest grains are found to be 3900±27 Ma in the eastern group of samples representing lowest parts of Fra Mauro formation (Fig. 2), 3932±23 Ma in the sample 14311 representing “subregolith basement breccia” at the top and 4002±16 Ma in the western group of samples.

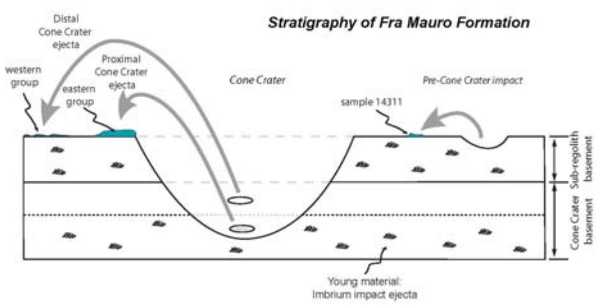

Figure 2: Stratigraphy of the Fra Mauro Formation according to the zircon age distribution patterns of the studied samples.

Discussion: Observed differences in the zircon age distribution patterns suggest stratigraphic layering within the sampled part of Fra Maouro formation questioning current understanding of the nature and origin of the formation sampled at the Apollo 14 landing site. The youngest zircon ages of 3900±27 Ma and 3932±23 Ma determined for the lowest and highest parts of the sampled crossection of the Fra Mauro formation are similar within the errors to the proposed age of 3914±7 Ma for the Imbrium impact [5], suggesting that the entire sequence was deposited within the 20-30 Ma time interval determined by the analytical ages.

It is therefore consivable that all sampled layers originated in the Imbrium impact following suggestion of [6, 7] that the total sampled thickness of the formation is a pristine Imbrium impact ejecta. An alternative interpretation proposed by [2, 8] suggests (i) that different breccias can represent entirely different impact deposits overlaying each other or (ii) mixing of different proportions of primary Imbrium ejecta with the older local material re-worked during the Imbrium ejecta deposition. In either of these scenarios the entire sequence must be deposited within about 30 Ma, suggesting possibility of several impacts occurring within this relatively short period of time.

References:

[1] Swann G. A. et al. (1977) *US GS PP, 880*, pp103. [2] Stöffler D. (1989) *LPITR, 03*, 138–144. [3] Crozaz G. et al. (1972) *Geochim.Cosmochim. Acta, suppl. 3,* 2917–2931. [4] Kirsten et al. (1972) *LPS III*, 1865–1889. [5] Liu D. et al. (2010) *Earth Planet. Sci. Lett., 319-320*, 277–286. [6] Wilhelms D. E. (1987) *US GS SPP, 1348*. [7] Hiesinger H. and Head J. W. (2006) *Rev. Min. Geochem., 60*, 1–81. [8] Morrison R. H. and Oberbeck V. R. (1975) *Proc. 6th Lunar Sci. Conf.*, 2503–2530.