Supplementary information

Uncertainties of age model and deposition rates

Our “Preferred Model” (Fig. 2) takes into account the uncertainty of the biostratigraphy (i.e. stratigraphic range of microfossils) in order to narrow the possible age range at a given depth. We assume, for example, that underlying beds cannot be younger than the overlying bed. This assumption excludes parts of the stratigraphic range of microfossils and results in the minimum (blue) and maximum (red) age-depth curve in Fig. 2. Our preferred model is then based on the simple assumption that the average grain size over a certain interval provides some information on either faster (coarse grained material such as conglomerate) or slower (finer grained material) deposition rates: Between 850 and ~1,200 m, the deposition rates would be extremely high (minimum curve) but the sequence is generally very similar to the interval between 600 and 850 m; Choosing the maximum for this intervals results in a similar age-depth curve for the 850-1,200 m interval. For the boundary between Unit III and IV, the mean age at the unit boundary has been picked. A single constant slope has been fitted through Unit IV for simplicity since this unit is of little relevance to this study.

The “Johnson Model” takes into account results from sedimentary facies analysis and is thus the most reliable for deposition rates (Tab. S1, Fig. 9). However, deposition rates have been calculated using three age-depth models, the “Preferred”, the “Johnson” and the “Maximum” Model and results are presented in Tab. S1. Even though the absolute rates vary up to a factor of 4, the overall pattern (i.e. the relative changes in deposition rate at a specific point in time) is similar (Tab. S1) and thus consistent with our interpretation.

LA-ICPMS analyses of glass inclusions

Trace element analyses were carried out at the Research School of Earth Sciences (ANU, Canberra). The newly installed Coherent CompexPro 110 laser ablation system is connected online to an Agilent 7700 quadrupole ICPMS and sample material is ablated within an ANU HelEx ablation cell. The following elements have been analyzed by LA-ICPMS: Li, Na, Mg, Si, Sc, V, Cr, Ni (isotopes $^{60}$Ni and $^{61}$Ni), Cu (isotopes $^{63}$Cu and $^{65}$Cu), Zn, Rb, Sr, Y, Zr (isotopes $^{90}$Zr and $^{91}$Zr), Nb, Ba, all rare earth elements (REE), Hf, Pb, Th and U. A 28 µm spot size and a laser energy of 5–6 J cm$^{-2}$ was used in all analyses with Ca as an internal standard. 10s pre-ablation time were followed by 40s ablation and 20s post-ablation time for wash out. Some glass inclusions were too thin for 40s ablation, resulting in a mixed glass inclusion/clinopyroxene analysis. All spectra were carefully reviewed and any mixed analyses removed from the final data.

International standard glass NIST-610 was used as internal reference material to correct for instrumental drift and glasses NIST-612 and BCR-2G have been repeatedly analysed as unknowns to monitor precision and accuracy during analyses. Precision is generally better than 5 %, except for Cr, Ni and Lu (7.9, 5.4 and 6.9 % for the BCR-2G standard, respectively) and accuracy is within ±5 % relative to the BCR-2G values of Jenner & O’Neill (2012) acquired on the same instrument except for Li (+13.6 %), Si (+11.4 %), Sc (+7.3 %), Cr (-9.4 %), Ni (+7.4 %), Rb (+8.2 %), Nb (-5.7 %) and Yb (-8.9 %). Trace element composition of glass inclusions and reference material are reported in Table S2.
Clinopyroxene-hosted glass inclusions

Glass inclusions in clinopyroxenes at Site U1438 record many different shapes and characteristics but we have not found any correlations between shape (i.e., round vs. angular) and compositional indices. Some irregular shapes are likely the result from cutting effects and LA-ICPMS analyses have shown that many inclusions are rather thin. Most obvious may be small reaction boundaries at the glass-crystal interface that show up as a thin bright rim inside the crystal and a thin darker rim inside the inclusion in BSE images.

Figure S1: BSE images of representative glass inclusions hosted in clinopyroxene.

These may result from post-entrapment modification and/or boundary crystallization but are considered to have only minor effects on our dataset for three reasons:

1) Our data is internally consistent and the differences observed between the >37 Ma and <37 Ma groups are thus unlikely to result from these processes. Even though the <37 Ma group is on average more evolved in terms of magmatic differentiation (e.g. Mg#, Fig. S3),
there is no change in the Fe-Mg exchange between host and inclusion (see further below) that could indicate increasing (or decreasing) disequilibria of host and inclusion and thus a systematic bias between the two groups.

2) Many trace elements, in particular the medium to heavy REE (Sm to Lu) and Y have similar partition coefficients between cpx and melt. Small amounts of boundary crystallization have thus only a very minor effect on the elemental composition of the inclusion.

3) EMP profiles through large inclusions do not record any major element variability except for spots that were too close to the host-inclusion interface and thus resulted in a mixed analysis (evident from optical observations; see below).

**Figure S2:** EMP profiles through some large inclusions and their corresponding optical microphotograph.
Glass inclusion versus host crystal

Figure S3: Mg#s of clinopyroxene hosts versus Mg# of glass inclusions. The $K_{D\text{Fe-Mg}}^{\text{cpx-liq}}$ of 0.27±0.03 (Putirka, 2008) is shown for comparison. Note that most inclusions trap melt compositions slightly higher in Mg# (and thus more primitive in terms of magmatic differentiation) than it would be expected for equilibrium with the cpx host.

Figure S4: TiO$_2$ in the glass inclusions versus TiO$_2$ concentration of the host (clinopyroxene and plagioclase).

Figure S5: Depth of sampling (in meters below seafloor, mbsf) versus Mg# of glass inclusions. Note the gradual shift towards more evolved (i.e. lower Mg#) compositions with decreasing depth (and thus age).
Figure S6: Major element concentrations of glass inclusions from Site U1438. A) FeO$^{T}$, B) MgO, C) CaO and D) Na$_2$O versus SiO$_2$ (all in wt.%). Note the offset between the two groups hosted in clinopyroxene, older (purple) and younger (yellow) than 37 Ma.

Clinopyroxene fractional crystallization model

For the clinopyroxene fractional crystallization model in Fig. 7, we used the Rayleigh fractional crystallization equation 9.3.3. of Albarède (1996), the following partition coefficients and initial elemental concentrations:

D$_{Ba}$: 0.001, Hart & Brooks, 1974 (Basaltic Andesite); $C_0$=100 ppm
D$_{Nb}$: 0.0081, Hauri et al., 1994 (Basalt); $C_0$=0.5 ppm
D$_{Th}$: 0.03, Dostal et al., 1983 (Basalt to Andesite); $C_0$=0.75 ppm
D$_{Yb}$: 0.6, Dostal et al., 1983 (Basalt to Andesite); $C_0$=4 ppm
HFSE and magmatic differentiation

Figure S7: A) Nb/Zr and B) Nb/Yb versus SiO₂ [wt.%].

References


