Collecting large-*n* U-Pb detrital geochronology data via rapid acquisition (300–1,200 analyses/h) laser ablation multicollector ICP-MS

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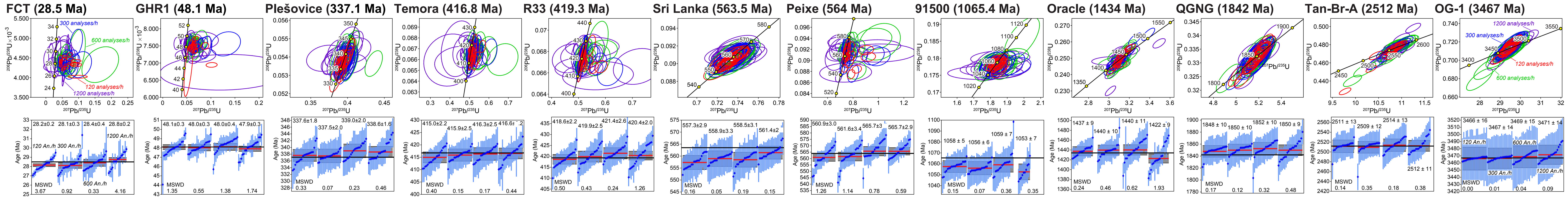
Overview and Conclusions

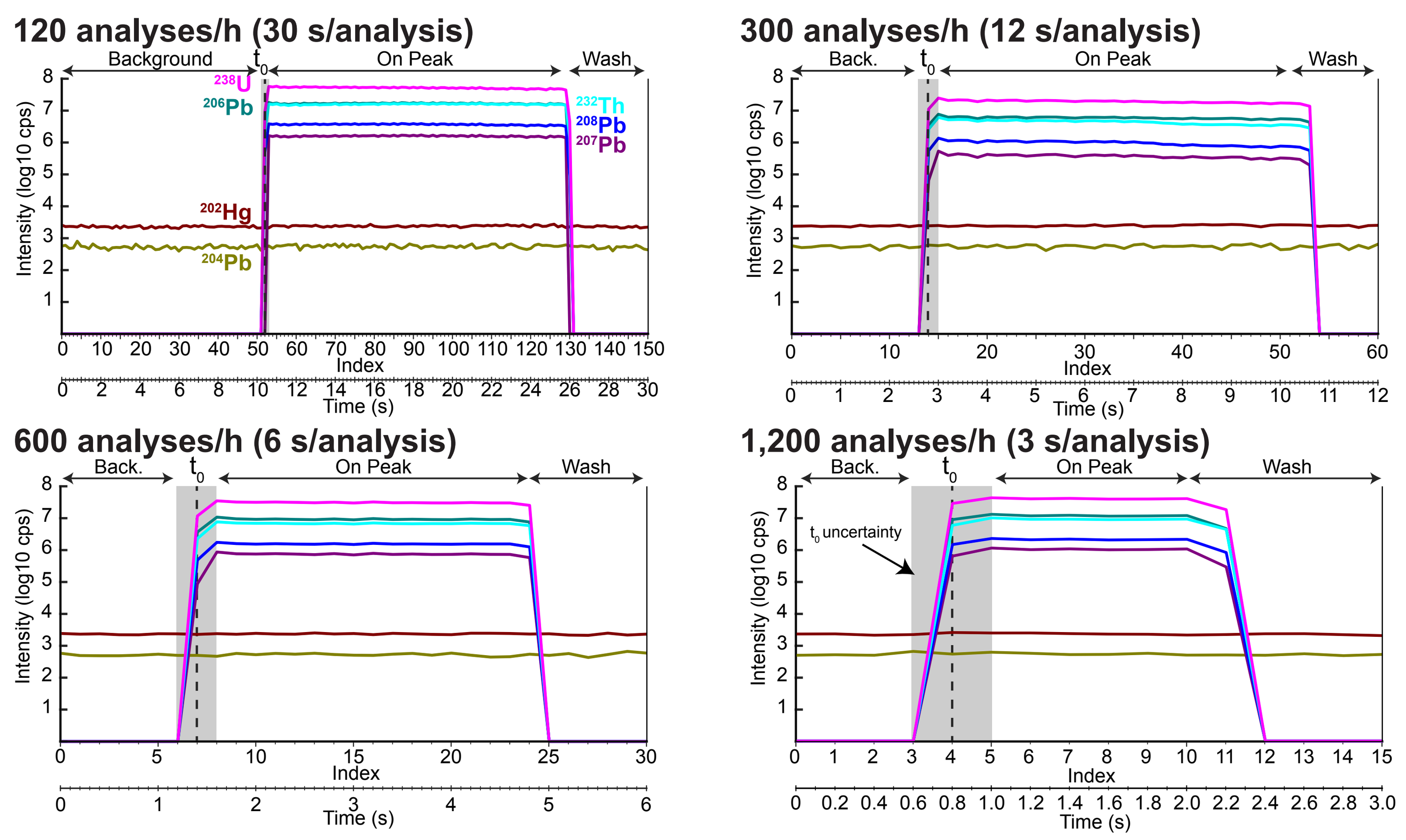
- We developed new methods to acquire detrital zircon U-Pb age dates by multicollector LA-ICP-MS at 120, 300, 600, and 1,200 analyses/h.
- Rapid acquisition is enabled by minor modifications to traditional methods including:
  - Total-count isotopic ratios and modified background subtraction for acquisition rates of 300–1,200 analyses/h.
  - Aerosol rapid introduction system (ARIS) and removal of homogenization chamber at the laser–plasma interface.
  - New data reduction software, *AgeCalcML*, that can handle automated laser schedules and time-resolved analysis.
- Qualitative and quantitative comparison show increased correspondence for age distributions comprising >300 age dates.
- Results highlight best practices for different detrital zircon (DZ) applications:
  - 120 analyses/h: Age distributions containing young (Cenozoic) populations.
  - 300 analyses/h: Most DZ applications, maximum depositional ages.
  - 600 analyses/h: Most DZ applications including highly complex distributions.
  - 1,200 analyses/h: Large-*n* provenance, scanning for specific populations.

Round Robin Testing



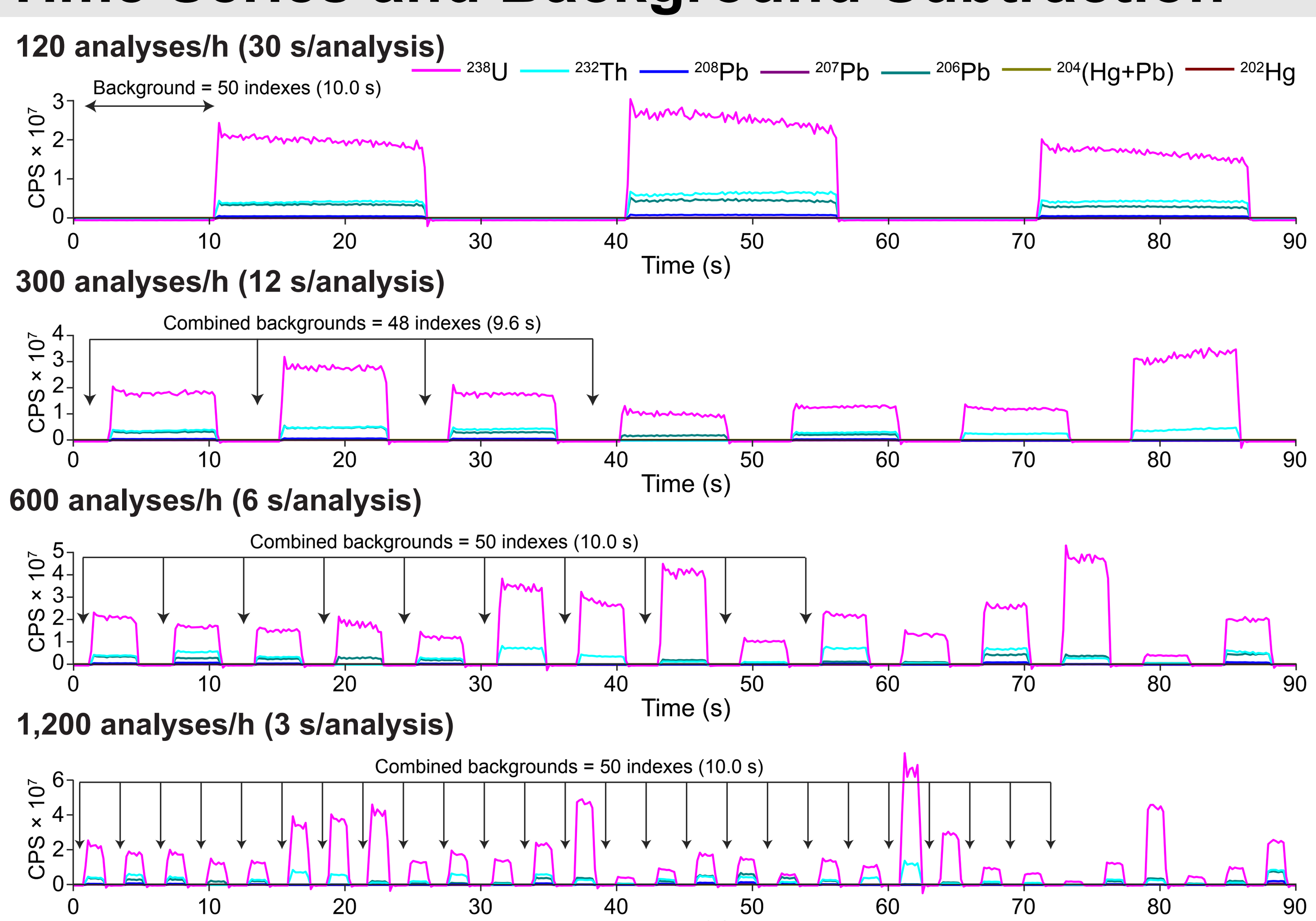
- Results yield concordant age dates at all acquisition rates for the twelve zircon reference materials analyzed.
- Weighted mean calculations including systematic (external) uncertainties show systematic offsets from high-precision ages.

Rates of Acquisition



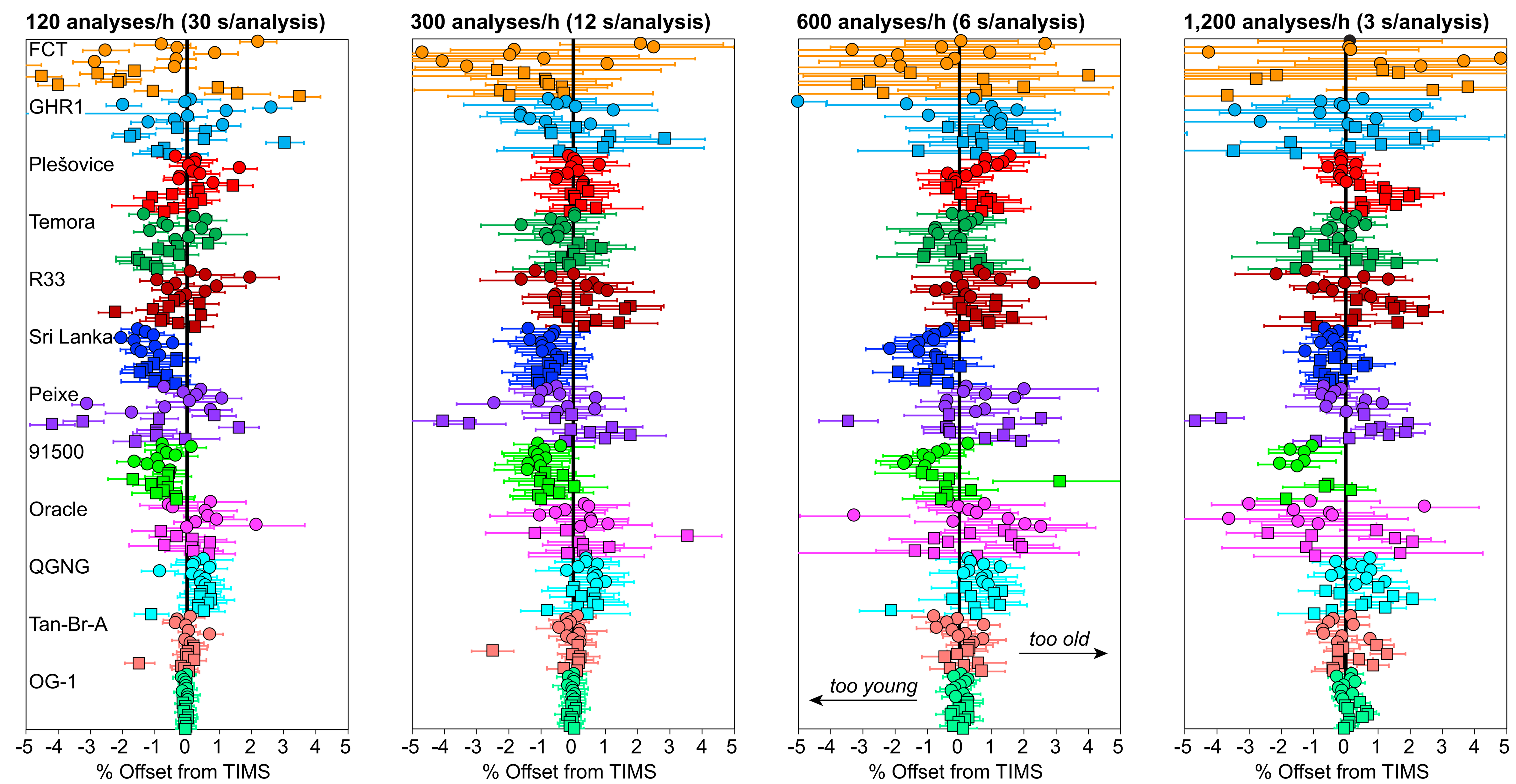
- All methods use 0.2 s resolution time-resolved analysis (TRA), Faradays with 3x10[11] ohm resistors for ^{238}U, ^{232}Th, ^{208}Pb, ^{207}Pb, ^{206}Pb, and discrete dynode ion counters for $^{204}(Hg+Pb)$ and ^{202}Hg.
- Each method is optimized to maximize the on-peak analysis with time zero (t_0) determined from TRA by threshold ^{238}U, and with a minimum spot size of 20 μm for 300–1,200 analyses/h.

Time Series and Background Subtraction



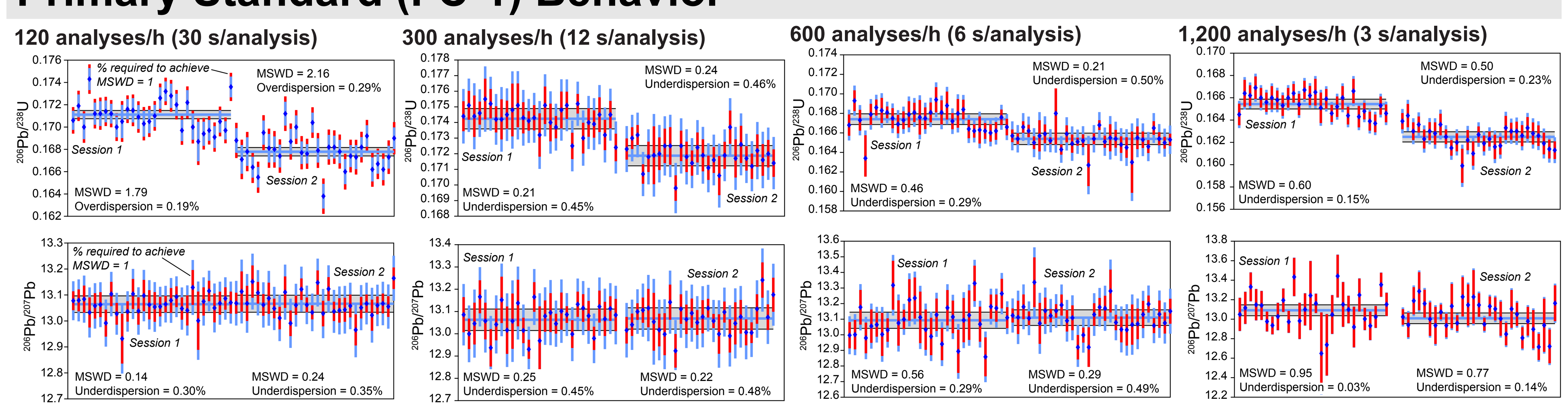
- Each isotopic mass is recorded as a discrete time series.
- The method of background subtraction for 300–1,200 analyses/h is modified by combining background measurements from multiple analyses to provide reasonable counting statistics.
- Standard error for 300–1,200 analyses/h is typically < 2% when combining backgrounds.

Offset from High-Precision Ages



- Accuracy is within 5% (often within 1–2%) and shows systematic offsets from high-precision age dates from thermal ionization mass spectrometry (TIMS).
- Uncertainty increases with faster acquisition rates, especially for young (Cenozoic) zircons.
- There is only a minor sacrifice in accuracy and precision for fast (300–1,200 analyses/h) acquisition rates.

Primary Standard (FC-1) Behavior



- Internal (random) uncertainties (blue bars) yield MSWD values close to 1, which means the reported precision appropriately accounts for the data dispersion.
- Red bars show the amount of uncertainty required to achieve MSWD = 1, and that in most cases the uncertainty is only slightly overestimated.

References

Dickinson, W. R., & Gehrels, G. E. (2008). Sediment delivery to the Cordilleran foreland basin: Insights from U-Pb ages of detrital zircons in Upper Jurassic and Cretaceous strata of the Colorado Plateau. American Journal of Science, 308(10), 1041-1082.

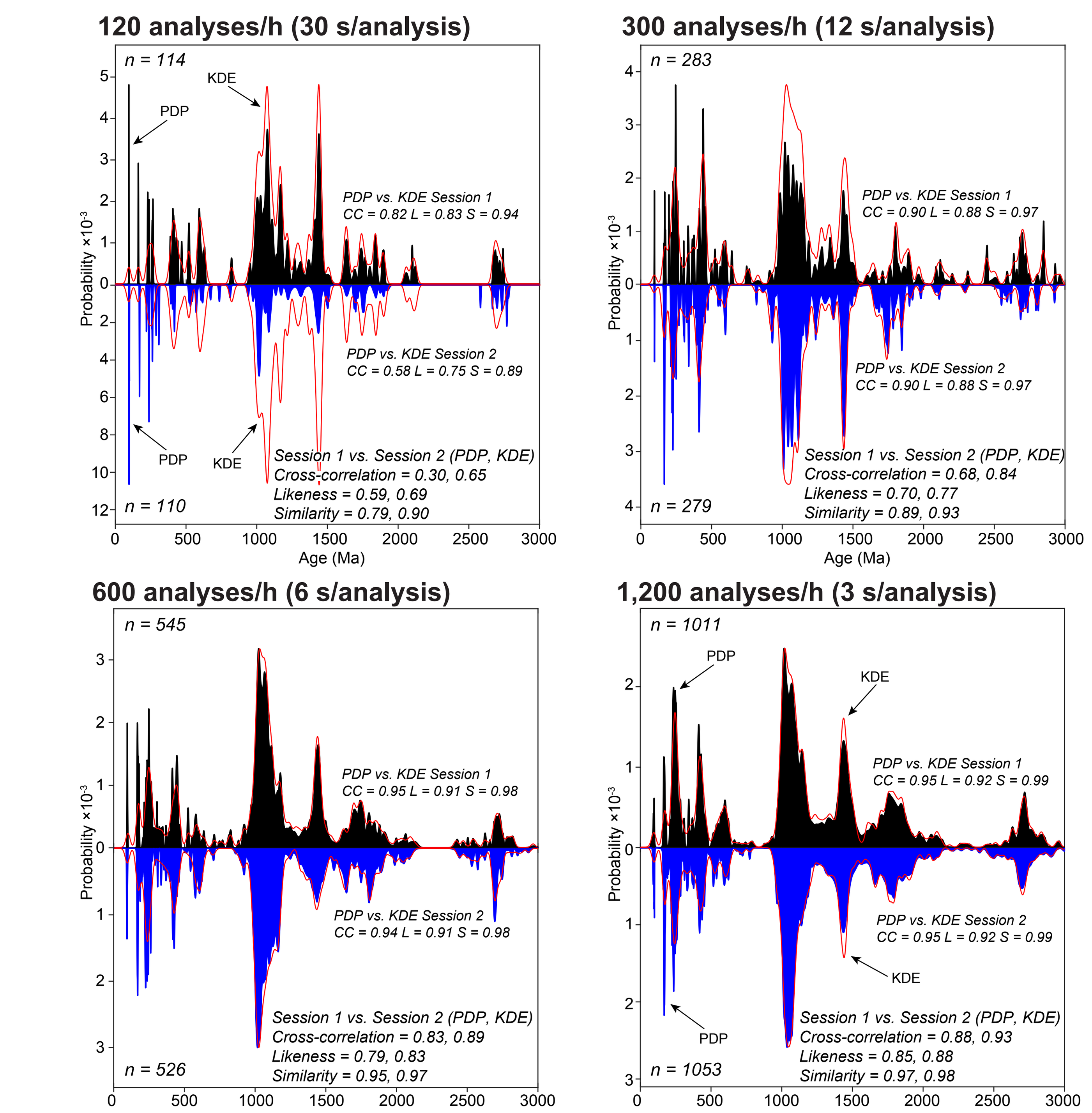
Gehrels, G. E., Dickinson, W. R., Darby, B. J., Harding, J. P., Manuszak, J. D., Riley, B. C., Spurlin, M. S., Finney, S. C., Girty, G. H., Harwood D.S., & Miller, M. M. (2000). Tectonic implications of detrital zircon data from Paleozoic and Triassic strata in western Nevada and northern California. Special papers - Geological Society of America, 133-150.

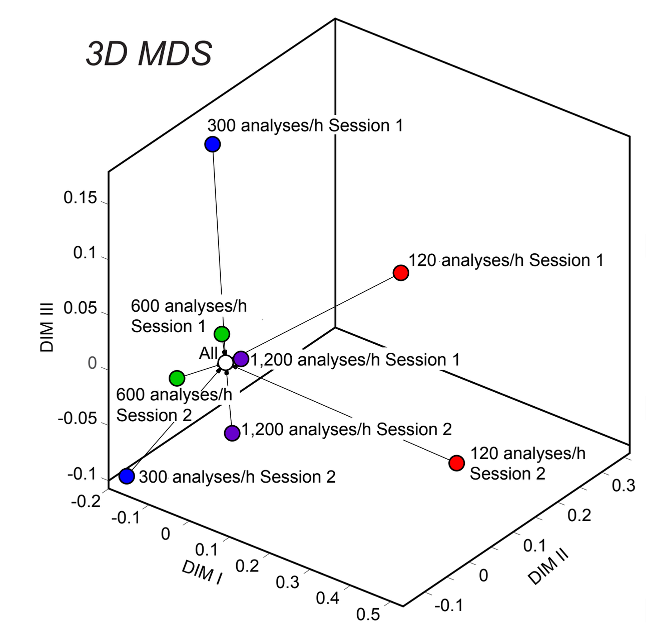
Pullen, A., Ibáñez-Mejía, M., Gehrels, G. E., Ibáñez-Mejía, J. C., & Pecha, M. (2014). What happens when n= 1000? Creating large-n geochronological datasets with LA-ICP-MS for geologic investigations. Journal of Analytical Atomic Spectrometry, 29(6), 971-980.

Satkoski, A. M., Wilkinson, B. H., Hietpas, J., & Samson, S. D. (2013). Likeness among detrital zircon populations—An approach to the comparison of age frequency data in time and space. Bulletin, 125(11-12), 1783-1799.

Saylor, J. E., Stockli, D. F., Horton, B. K., Nie, J., & Mora, A. (2012). Discriminating rapid exhumation from syndepositional volcanism using detrital zircon double dating: Implications for the tectonic history of the Eastern Cordillera, Colombia. Bulletin, 124(5-6), 762-779.

Detrital Application





- CP40, a sandstone sample from the Cretaceous Wahweap formation near Henrieville, UT that was analyzed by Dickinson and Gehrels (2008) and subsequently analyzed by Pullen et al. (2014) for large-*n*, was tested at the four rates of acquisition by analyzing the same *n* at each hourly rate (e.g., 600 grains at 600 analyses/h).
- Results plotted as kernel density estimates (KDEs, with a 15 Myr bandwidth) and probability density plots (PDPs) show increased similarity for the 600 and 1,200 analyses/h tests.
- Quantitative comparison of PDPs and KDEs shows a systematic increase in correspondence based on Similarity (S, Gehrels, 2000), Likeness (L, Satkoski et al., 2013), and Cross correlation (CC, Saylor et al., 2012).
- Multidimensional scaling (MDS) based on CC dissimilarity converted to Euclidean distance shows that distributions with >300 ages are more similar (closer together) than with fewer ages.