



Forensic characterization of the Wilcox: a new multi-disciplinary approach to support stratigraphic correlation sediment dispersal mapping and reservoir zonation

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The Power of Integration: Turning challenges into opportunities





| Outline

Technical collaboration (Chemostrat / PetroStrat)

Biostratigraphy – Paul Cornick (PetroStrat) - Thursday

Chemostratigraphy / PETM – David Riley / Tim Pearce (Chemostrat) – Thursday

Wellsite Chemostratigraphy – David Riley – This session

This talk (Sandtrak)

- **Building a correlation framework (Biostrat / Chemostrat)**
- **Inorganic geochemistry (ICP)**
- **Quantitative (QXRD)**
- **Heavy mineral analysis (Raman)**
- **Garnet typing (Raman)**
- **Grain textural analysis**
- **Detrital zircon (U/Pb) dating (assemblages / MDA)**

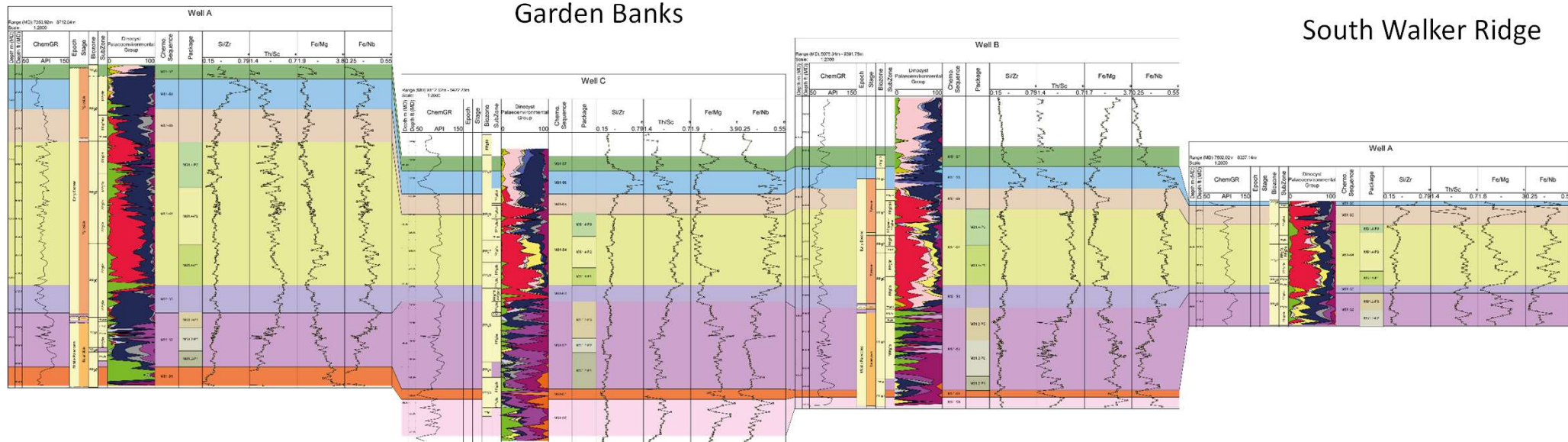
Chemostrat & Biostrat

Alaminos Canyon

Keithley Canyon

Garden Banks

South Walker Ridge



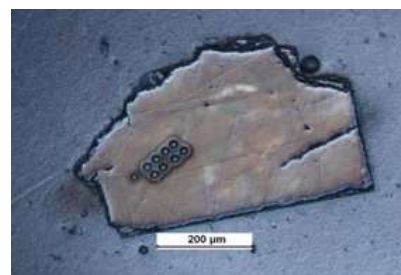
Strong correlation between Chemostrat and biostrat for sequences
Provides a robust stratigraphic / chronostratigraphic framework for
constraining more forensic data

| What is the problem ?

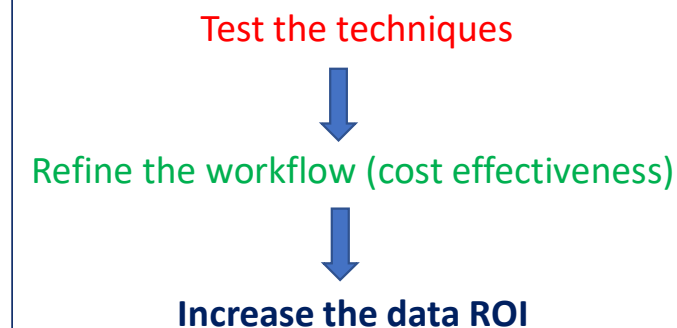
Adapt the tools for forensic characterisation

Sandtrak[®]: Seeks to establish an optimized workflow based on the integration of a series of techniques integrated to produce a comprehensive geological solution applicable for regional exploration, field development and sub-biostrat reservoir of flow units

- Inorganic geochemistry (XRF / ICP)
- Quantitative (QXRD)
- Heavy mineral analysis (Raman)
- Garnet typing (Raman)
- Grain textural analysis (recycling vs 1st cycle)
- Detrital zircon, apatite, titanite (U/Pb) dating / MDA
- Grain chemistry fingerprinting (LA-ICP-MS) – rutile, tourmaline
- Automated mineralogy (QEM-SCAN) – RQ controls / lithics
- Facies analysis (differentiation of process vs provenance)
- PSL - Reworked Biostratigraphy
- Statistical modeling and GIS mapping



Not interested in provenance! But provenance tools are critical to improving understanding - Compositional variations caused by source area, climate, process and diagenesis



QXRD: bulk mineralogy

Well A (Alaminos Canyon)

Limestone top Wilcox

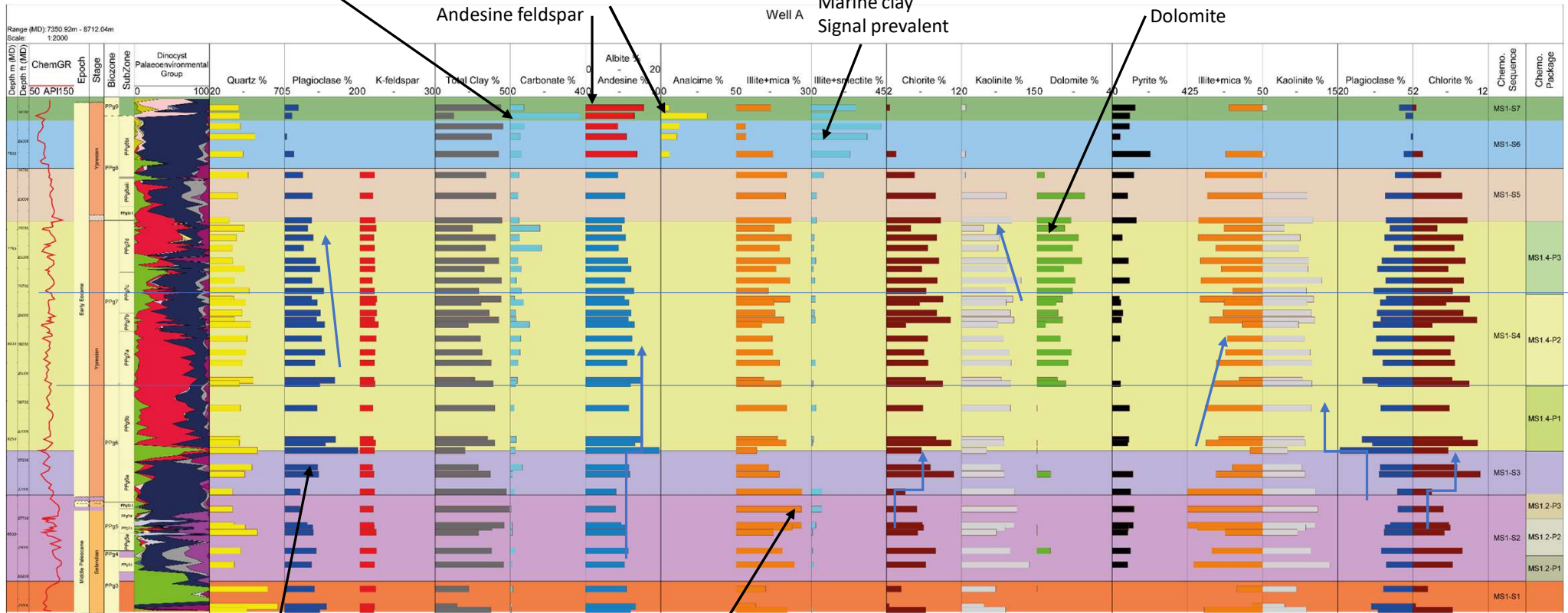
Mafic volcanics & Analcime

Andesine feldspar

Well A

Marine clay
Signal prevalent

Dolomite



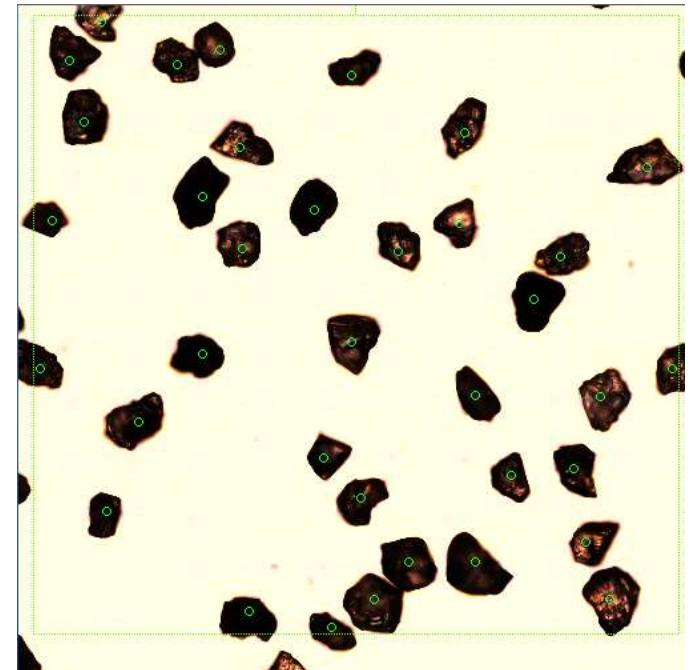
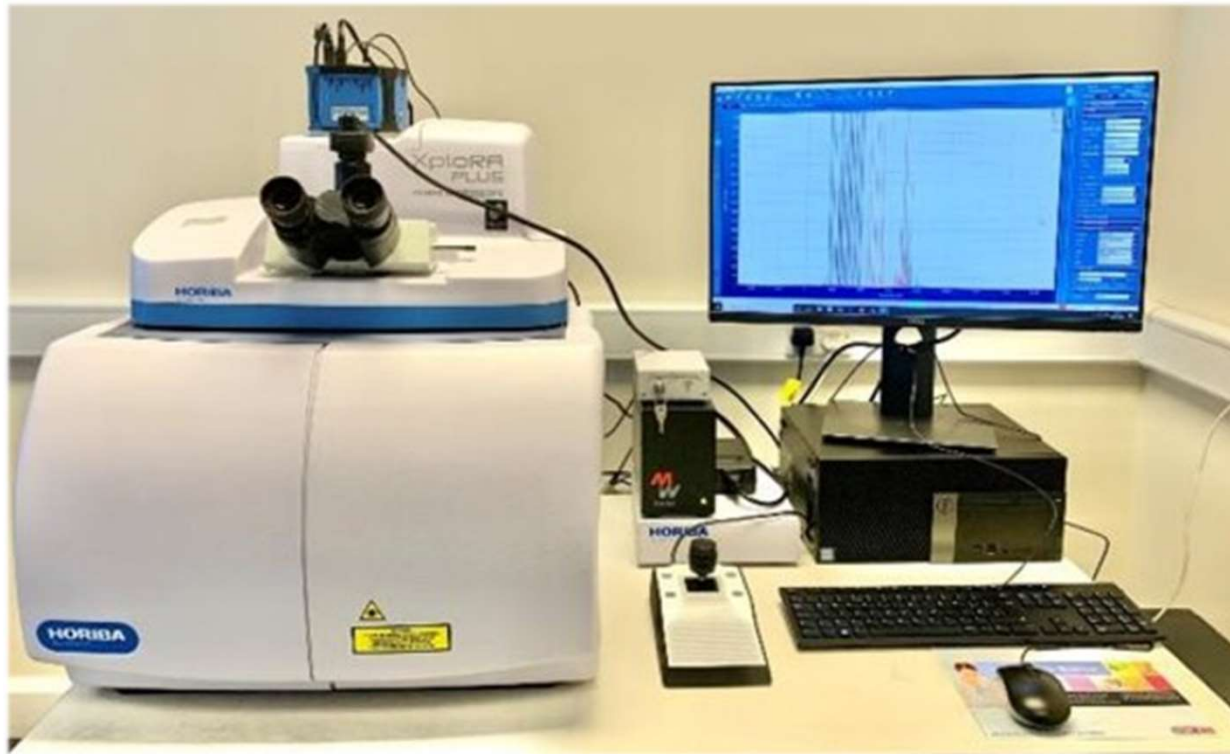
Stepped increase in Plagioclase

Marine clay signal

Mafic Metamorphic – epidote, Cr Spinel, Chloritoid

Mafic Volcanics – olivine, pyroxene, amphibole

| Raman Mineral Analysis

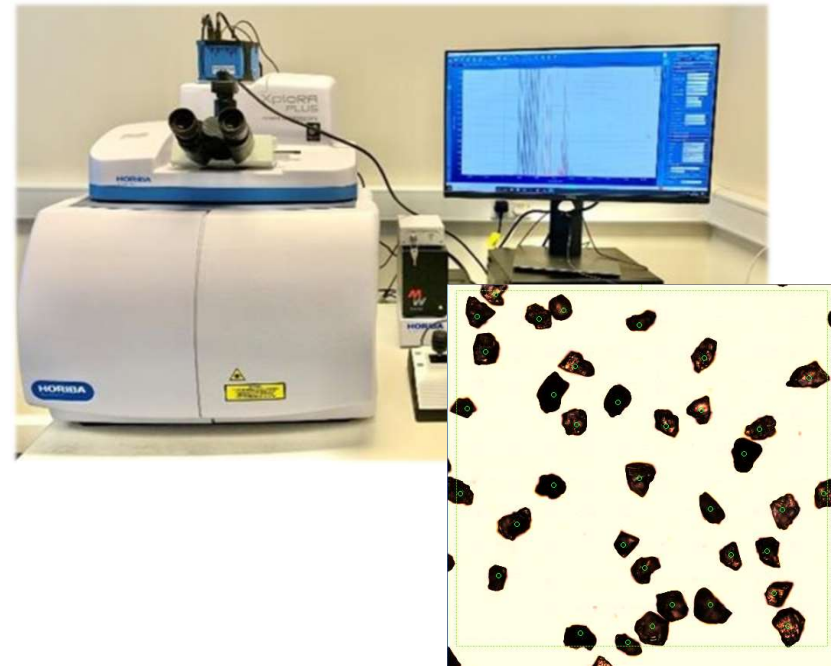


Devil in the detail – Raman - to look more closely and consistently at accessory mineralogy

Raman Mineral Analysis

Raman Spectroscopy

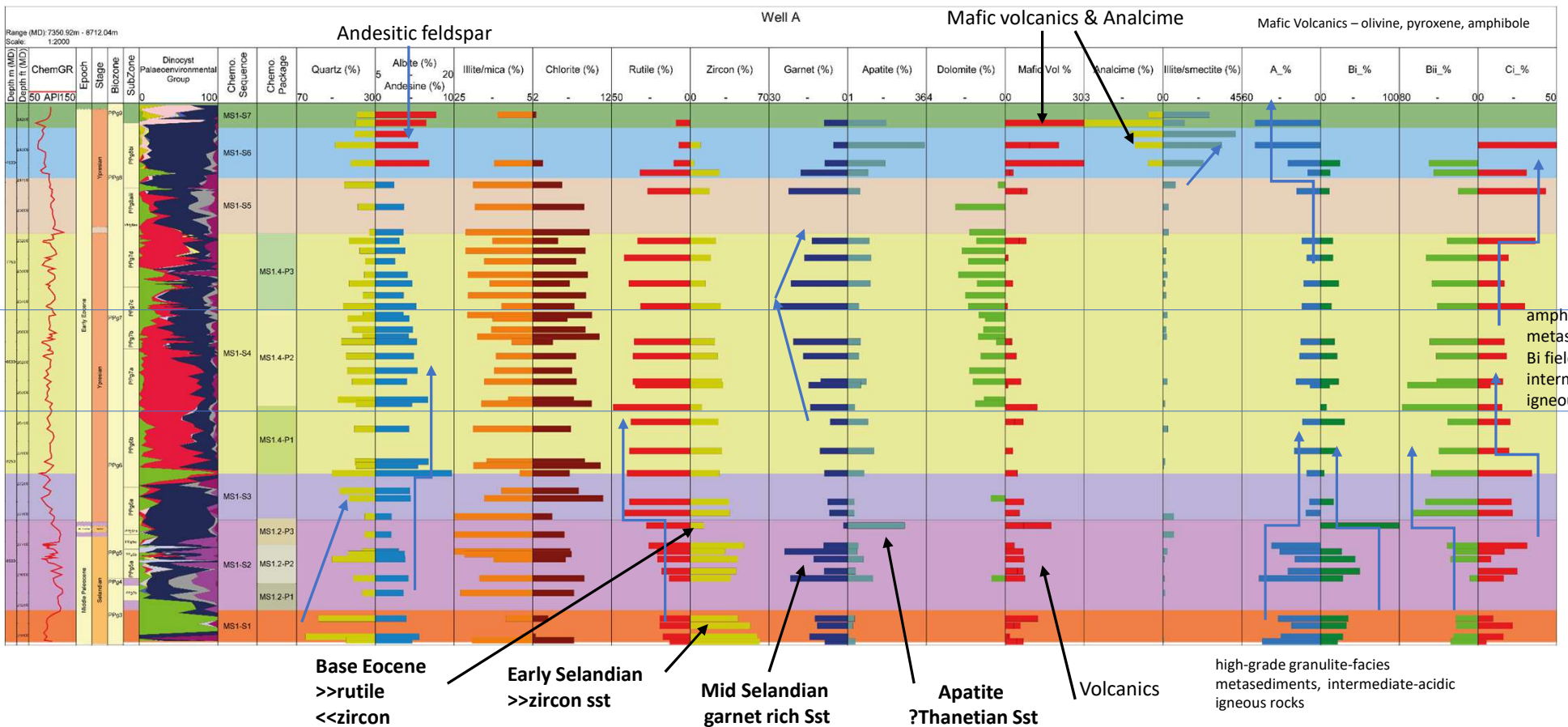
- Non-destructive method
- Based on chemistry and structure of a mineral, thus it can differentiate both:
 - Solid solution series (e.g. garnet end-members)
 - Polymorphs (e.g. TiO_2 HMs; aluminosilicates)
- Automated mineral identification (40-250 micron)
- High quality, statistically meaningful data: analysis of ~2500 grains per sample
- Textural Analysis, Garnet typing
- Feldspar varieties can be distinguished
- High throughput (24/7 analysis)
- Automated & not operator-dependent – removes operator bias



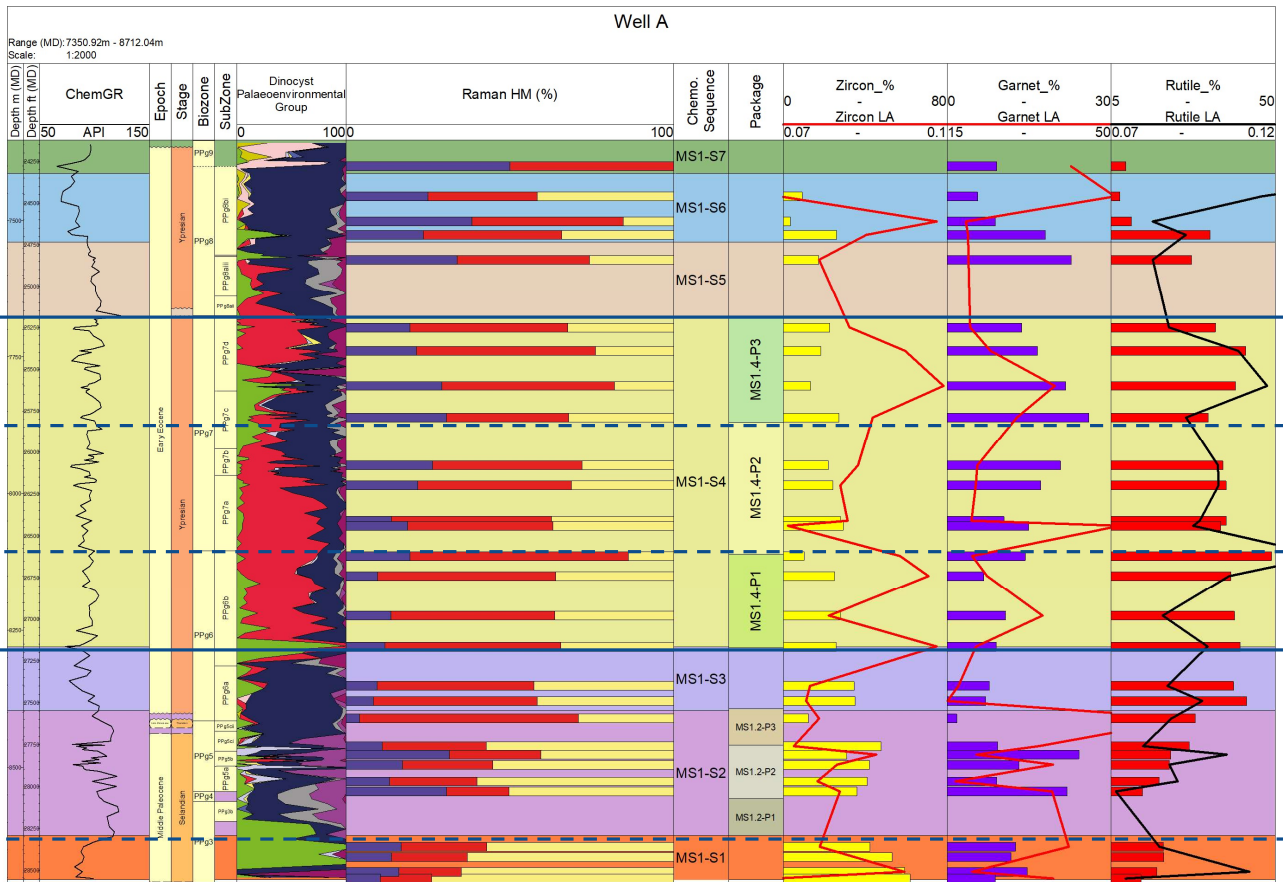
Raman spectroscopy is the measurement of the wavelength and intensity of scattered light from molecules. The Raman scattered light occurs at wavelengths that are shifted from the incident light by the energies of molecular vibrations

Raman – HMA & garnet typing (+QXRD)

Well A (Alaminos Canyon)



Well A: Raman HMA data and texture



Grain textural data provide additional characterisation of sandstone packages for Provenance / Seq strat (Exploration) – BUT also reservoir Stratigraphy (Development)

Low zircon contents – but an Influx of coarser grained first cycle zircons in Seq S6, with an increase in smaller garnet

Low zircon contents – but an Influx of coarser grained first cycle zircons in Package 4P1 and in 4P3 with coarser garnet and rutile
4P2 lower zircon abundance and size and <angular Rutile and garnet similar grain-size and abundance
Climatic warming – inc in rainfall and weathering and sedimentation rates

Zircon size and shape (angularity) decreasing with abundance – decreasing energy with fine sand to silt grade zircons

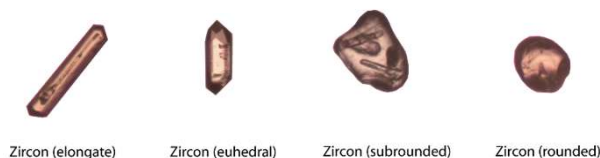
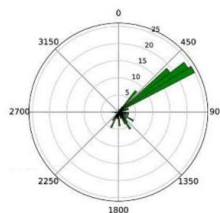
Rutile and garnet similar grain-size and abundance etc in S1 (coarser first cycle rutile)

Sandtrak Workflow

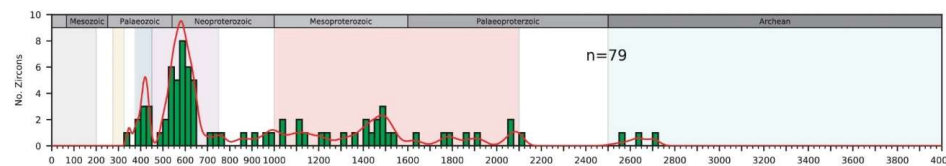
Detrital Zircon Geochronology

Sample and Data Analysis

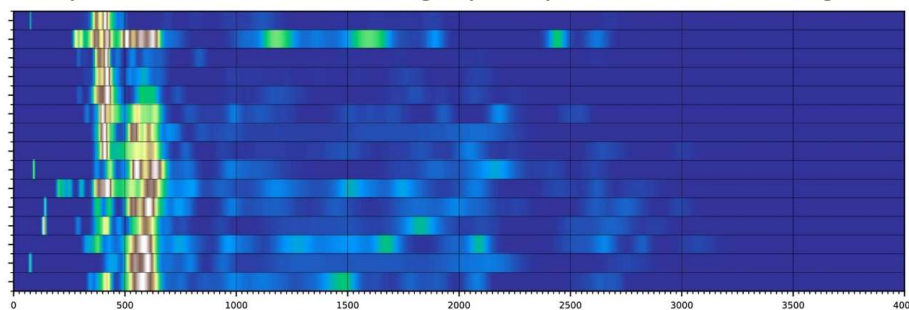
- Scanning electron microscope analysis to identify and map zircons by scanning for hafnium
- **No zircon picking – population assessment not targeting MDA**
- 100 zircons analysed per sample
- Centre of each grain is targeted and ablated using LA-ICP-MS
- A zirconium silicate → $ZrSiO_4$
- Highly refractory and ultra-stable
- Absorbs U but rejects magmatic Pb ('common Pb')
- Two independent ages:
 - $^{206}Pb/^{238}U$ – ^{238}U has half life of 4.46 billion years
 - $^{207}Pb/^{235}U$ – ^{235}U has a half life of 704 million years
 - **Use one age to verify the other – “concordance”**



Detailed analysis of individual samples

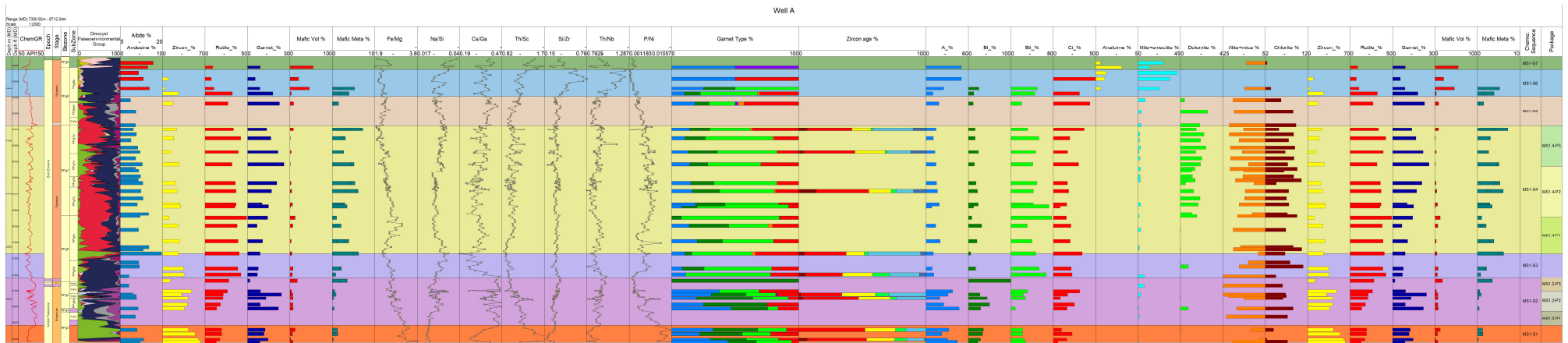


Easy observation of stratigraphic provenance changes



I Sandtrak data summary

ICP, XRD, HMA, Garnet typing, Isotopic, Biostratigraphy, Biofacies, E-logs



Multi-disciplinary, cross validated and integration data for comprehensive characterisation of the Wilcox

I Conclusions

Closing remarks

- Robust and complimentary correlation framework (Biostrat / Chemostrat)
- Inorganic geochemistry (ICP) – strong Chemostrat correlation but also mapping lateral provenance trends and tool for reservoir zonation. Climate / weathering influence
- Quantitative (QXRD) - Provenance, volcanics, weathering and palaeoenvironmental data
- Heavy mineral analysis (Raman) – major Wilcox 1 / 2 HMA switch – intra Wilcox 1 & 2 subdivision, lateral provenance trends
- Garnet typing (Raman) – Garnet type switch at base Eocene / intra Wilcox 1
- Grain textural analysis (Raman) – major influx of coarser grained / angular zircons (+plagioclase+ chlorite) with increased run off associated with PETM
- Detrital zircon dating (underway but preliminary data differentiates Wilcox 1 & 2). Fluctuations in Mid Cont. vs Western Cordilleran / Laramide input
- More wells under analysis
- Isotope (C-O) and Automated mineralogy underway

New integrated multidisciplinary data – provides the information to ground truth geological models