The Characterization of Trough and Planar Cross-Bedding from Borehole Image Logs

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Abstract

Conventional analysis of FMI images for the determination of palaeoflow direction in dune fields of interdune basins are prone to errors due to trough cross-bed structures. This study aims to demonstrate that the methodology for the analysis of trough cross-beded structure at large to an accuracy, the dip can be overestimated by as much as 10°. The conventional technique can result in large errors in palaeoflow direction due to the subjective errors that are observed in the borehole axis and the trough axis. This effect is conventionally accounted for by taking the vector mean of a large set of azimuthal determinations from a depth interval of typically greater than 30 m and assuming that the errors cancel themselves out. The technique involves vertical resolution.

We present an analytical model describing the intersection curves that result from the intersection of a vertical borehole with a mathematically generated trough cross-bedded structure. Analysis of the new model allows deviation from idealised behaviour that increases in the dip and angle of the borehole axis, and in the direction of the trough axis. Analysis of the new model shows that the borehole axis and the trough axis are not perpendicular. as accurately as possible, the dip can be reconstructed by as much as 10°, and the azimuth can be recovered by 10°. The problem is recognised and conventionally accounted for by averaging the results from many intersection curves. This improves the accuracy of dip and azimuth determinations. This paper presents results from an analytical capability characterised by (a) greatest improvement in accuracy in dip and azimuth determination, (b) minimal information concerning the width of the trough and the offset of the borehole axis from the trough axis, and (c) enhanced vertical resolution allowing accurate dip and tilt values to be obtained from individual intersection curves. This information enables each trough to be accurately and uniquely mapped in three dimensions in the subsurface.

Conventional FMI Analysis

- FMI is an electrical technique used in boreholes to map the bedforms and structure around the perimeter of the borehole.
- FMI images of planar bedforms cut the borehole with sinusoidal intersection curves.
- The azimuth of the plane indicates the dip of the cross-bedding.
- The position of the minimum indicates the azimuth of the maximum dip (parallel direction).

Problems with Conventional FMI Analysis

- In many cases the building is NOT PLANAR.
- Trough cross-bedded structures produce intersection curves that are similar to true sinusoids, but are significantly different.
- This gives large errors in dip and azimuth.
- The position is incorrect and the azimuth is not accounted for.
- The azimuth is not explicit in the new model equation. It is derived by fitting the results from many intersection curves.

New Model

- Based on equations for the intersection of a circular borehole with a plane
- Parameters provided by the model are:
  - Azimuth, α
  - Dip, δ
  - Blindly applied to all data leads to errors in non-planar bedded systems

Properties of the New Model

- The new model gives accurate values of dip, azimuth, diameter ratio, and offset.
- The azimuth is not explicit in the new model equation. It is derived by fitting the intersection curves from numerical images, with the azimuth (blue arrow) according to that intersection closest to the mires (green and yellow arrows)

Testing the New Model

- The new model fitted the data better than the conventional model in the majority of cases
- Mean values for all 39 curves
  - Errors in Conventional FMI: 36.4 ± 19.8°
  - Errors in New FMI: 0.98 ± 0.1°
- Durbin-Watson (<0.8) 0.6631 1.050
- Adjusted R²: 84.1% 97.9%

Subsurface Structure Mapping

- The new model provides data on mean dip and mean azimuth for sets of curves spanning a significant vertical interval
- The new model provides highly accurate values of dip, azimuth, trough radius and offset for individual structures.
- This allows them to be mapped uniquely in the subsurface.

Summary I

- The conventional method for analysing FMI intersection curves often leads to large errors and low vertical resolutions in trough-bedded systems.
- We have produced a new method for analysing FMI intersection curves that can be used to analyse plane and trough-bedded systems accurately with high resolution.

Summary II

- The conventional method provides data on mean dip and mean azimuth for sets of curves spanning a significant vertical interval.
- The new method provides highly accurate values of dip, azimuth, trough radius and offset for individual structures.
- This allows them to be mapped uniquely in the subsurface.