The Characterization of Trough Cross-Bedded Sedimentary Structures and Palaeoflow Direction from Down-Hole FMI Images

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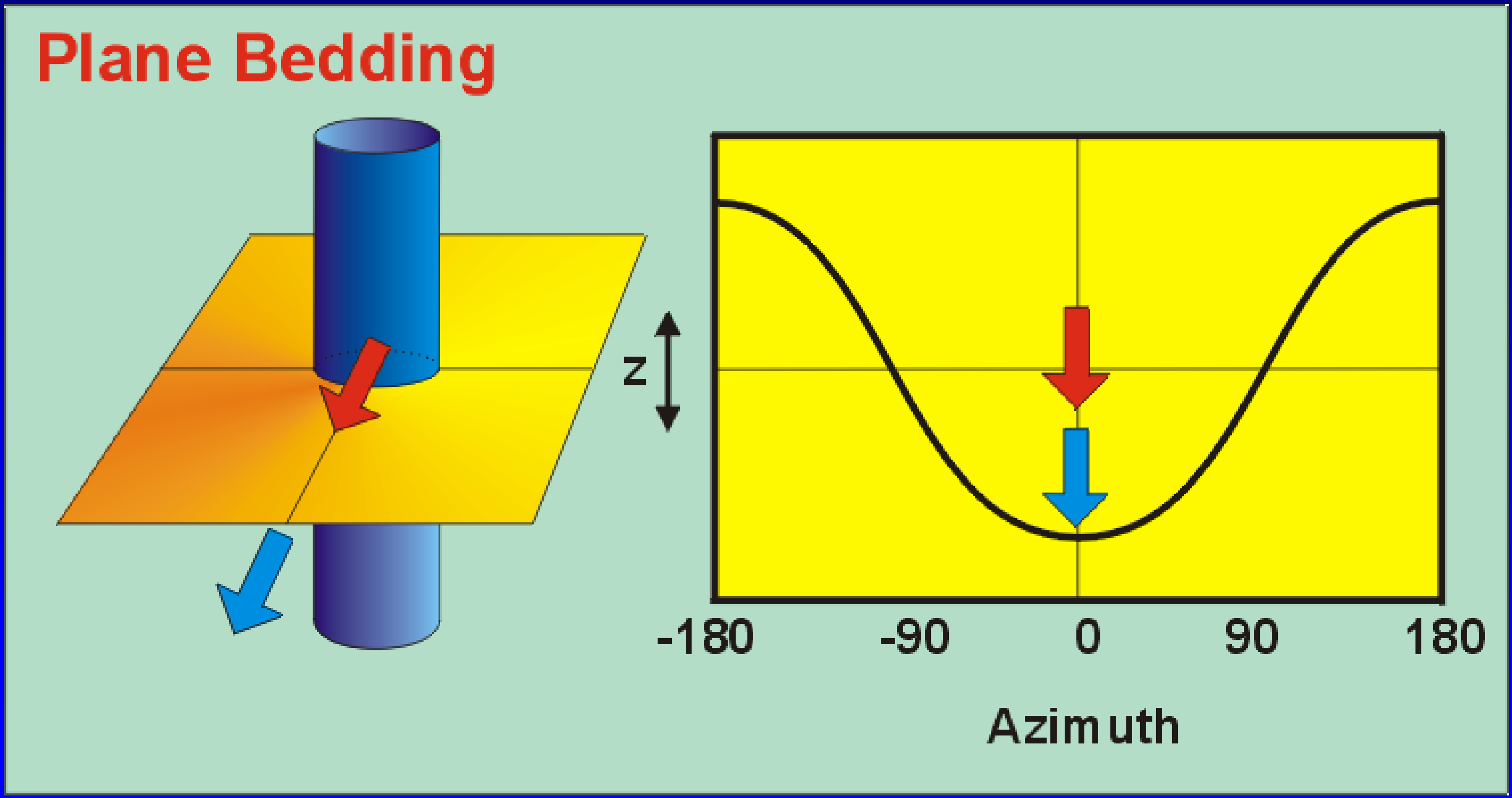
Structure

- Conventional FMI Analysis for Palaeoflow Direction
- Problems with the Conventional Technique
- A New Model for FMI Intersection Curves
- Application to FMI data
- Summary

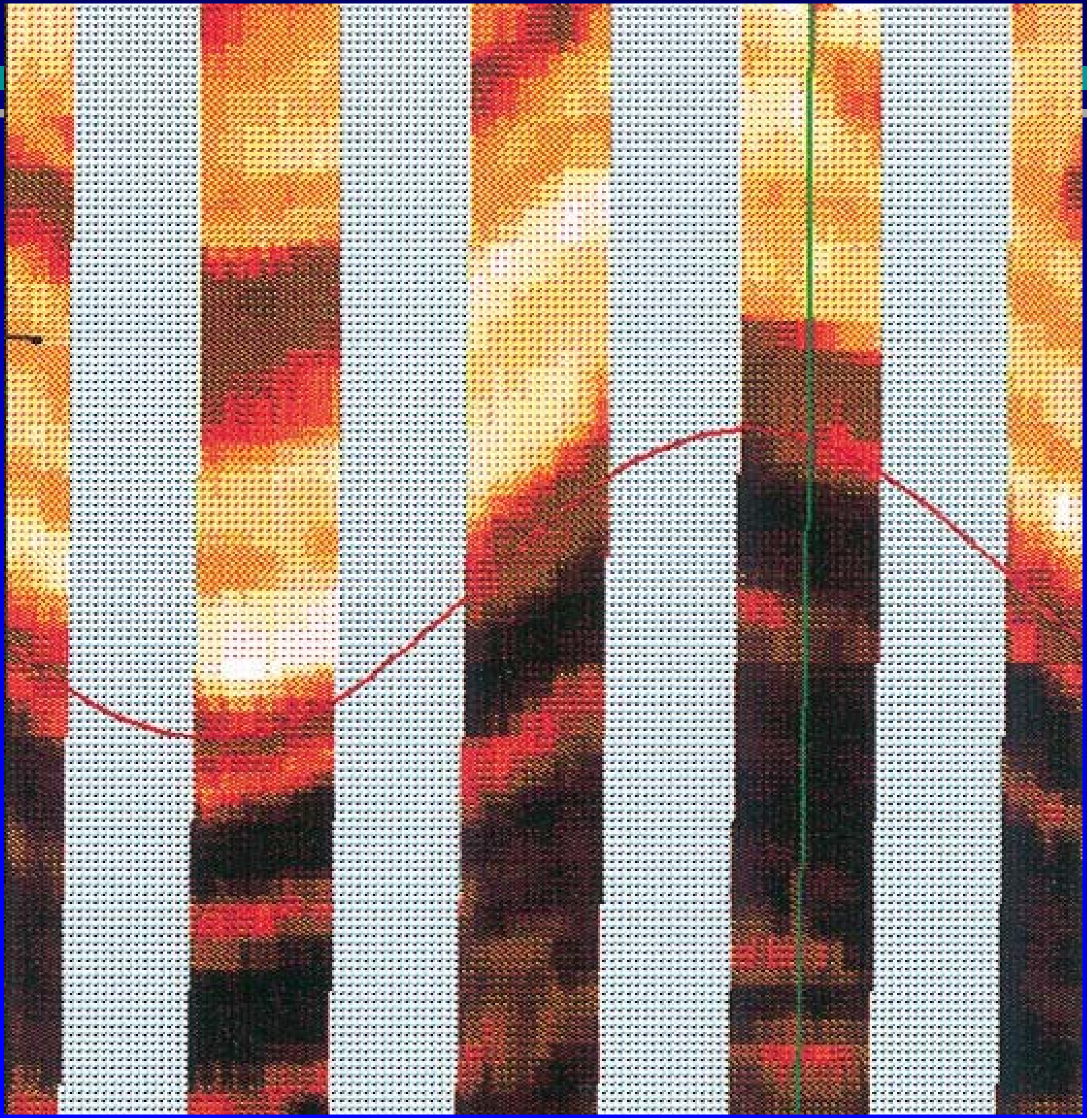
Conventional FMI Analysis

- FMI is an electrical technique used in boreholes to image bedding and fractures around the perimeter of the borehole
- FMI images of planar bedforms cut the borehole with sinusoidal intersection curves
- The amplitude of the curves indicate the dip of the bedding
- The position of the minimum indicates the azimuth of the maximum dip (palaeoflow direction)

FMI Intersection Curves - Plane Bedding



FMI Intersection Curves - Data



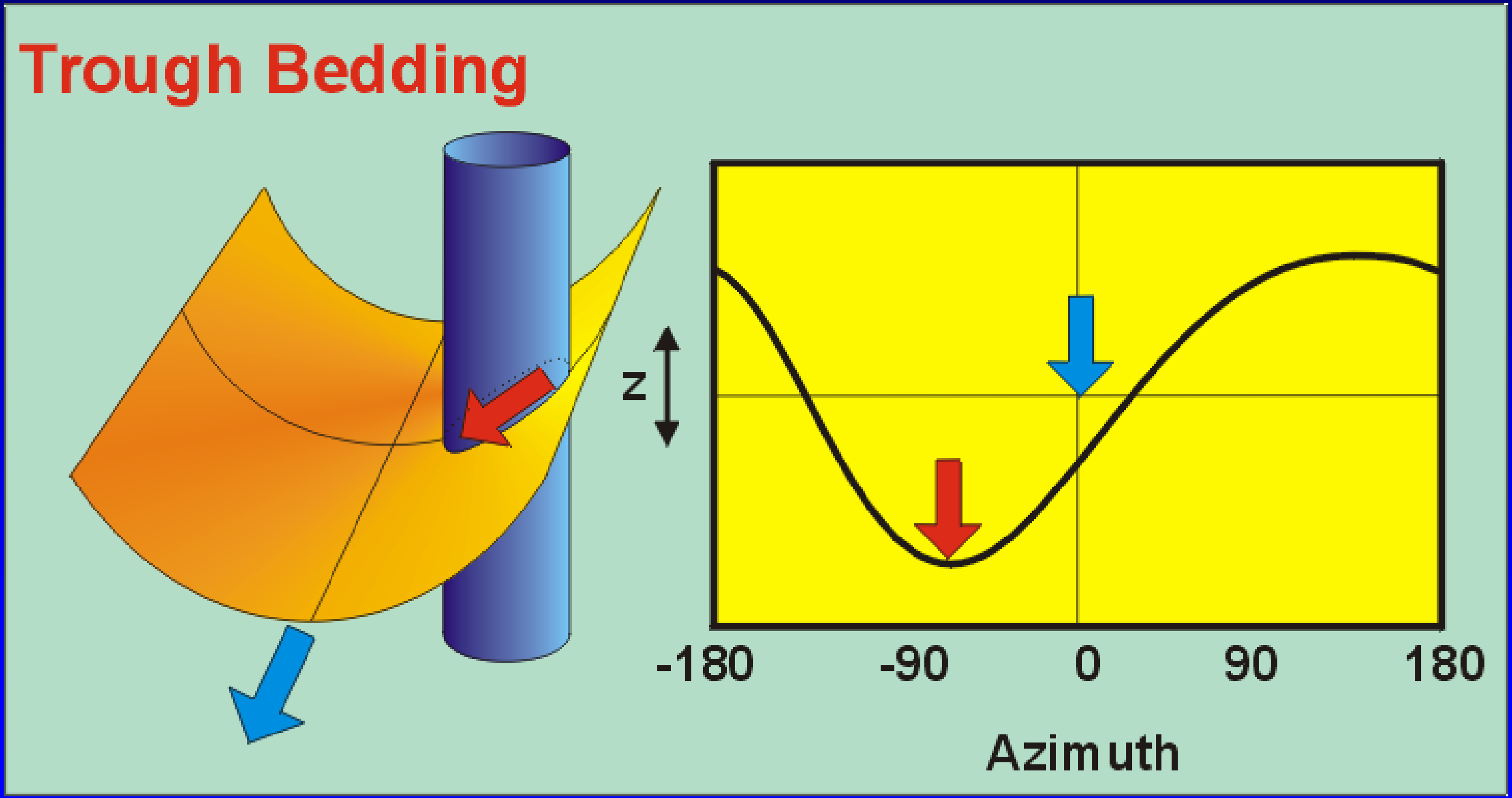
Problems with Conventional FMI Analysis

- **In many cases the bedding is NOT PLANAR**
- **Trough cross-bedded structures produce intersection curves that look similar to true sinusoids, but are significantly different**
- **This gives large errors in dip and azimuth**
- **The problem is recognised and conventionally accounted for by averaging the results from many intersection curves**
- **Then hoping the errors cancel out!!!**

Conventional FMI Analysis

- They don’t!
- The resulting data loses its vertical resolution (by about 50 times)

FMI Intersection Curves - Trough Cross-Bedding



Errors in Conventional FMI Analysis

There is no *a priori* knowledge of where the borehole intersects the trough

- **If the borehole intersects the axis of the trough, the curve is similar to the plane case**

- **If the borehole does not intersect the axis of the trough, the side walls have the following effects:**
  - **The dip will be overestimated by as much as +40^o**
  - **The azimuth will be in error by as much as ±90^o**

Conventional Model

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

New Model

- Based on equations for the intersection of a circular borehole with a hemi-circular trough
- Parameters provided by the model are:
  - Azimuth, ϕ
  - Dip, θ
  - Ratio of trough radius to borehole radius, d
  - Ratio of offset distance to borehole radius, b
- Blindly applied to all data does not lead to errors in plane or non-plane bedded systems

New Model Equation

In its most general form the intersection equation is:

$$z = \frac{1}{\cos\theta}\left[\sin\theta\cos(\alpha-\varphi)+\sqrt{d^2-(\sin(\alpha-\varphi)-b)^2}\right]$$

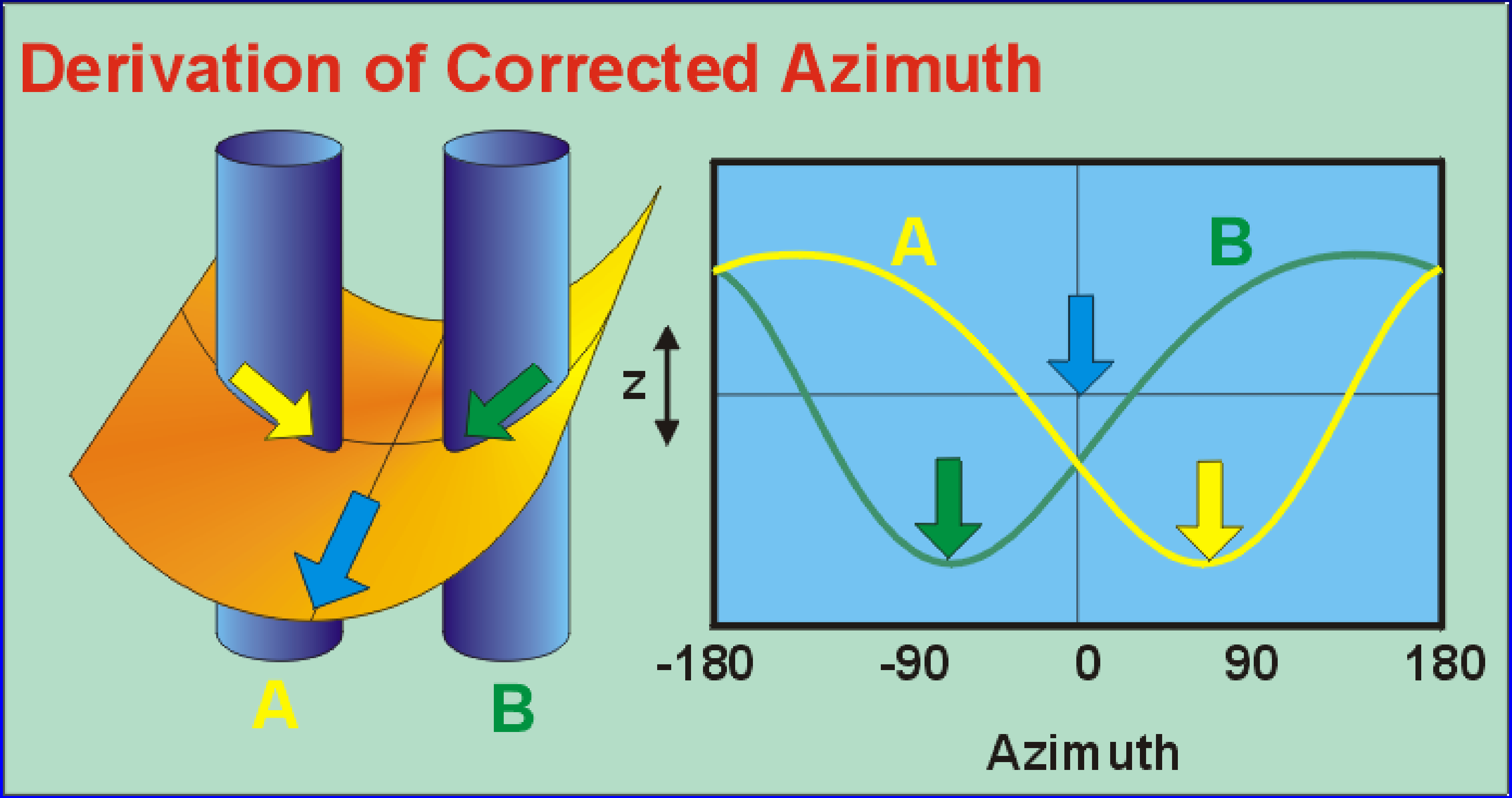
θ = Dip

d **= Ratio of trough radius to borehole radius**

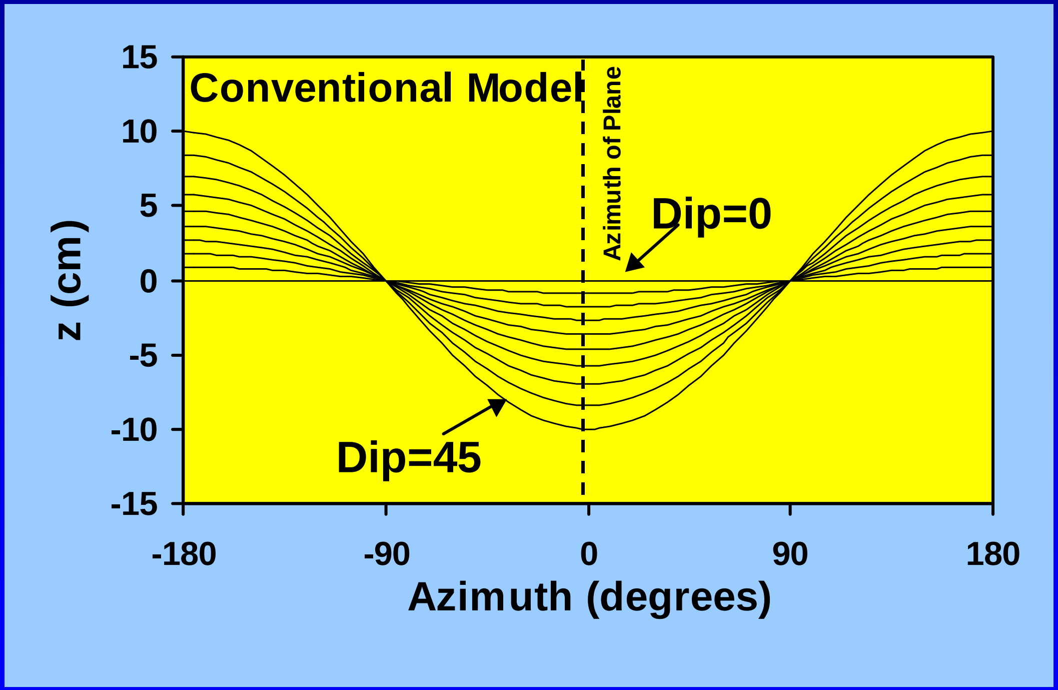
b **= Ratio of offset distance to borehole radius**

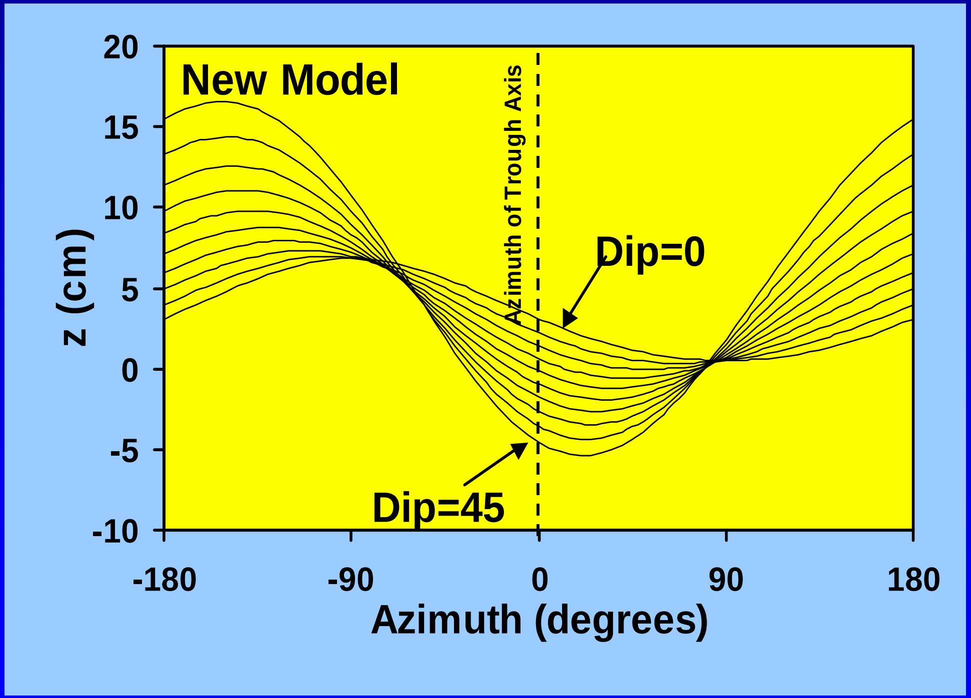
Azimuth, ϕ **is derived from** φ **and** α ***by symmetry***

Derivation of Corrected Azimuth

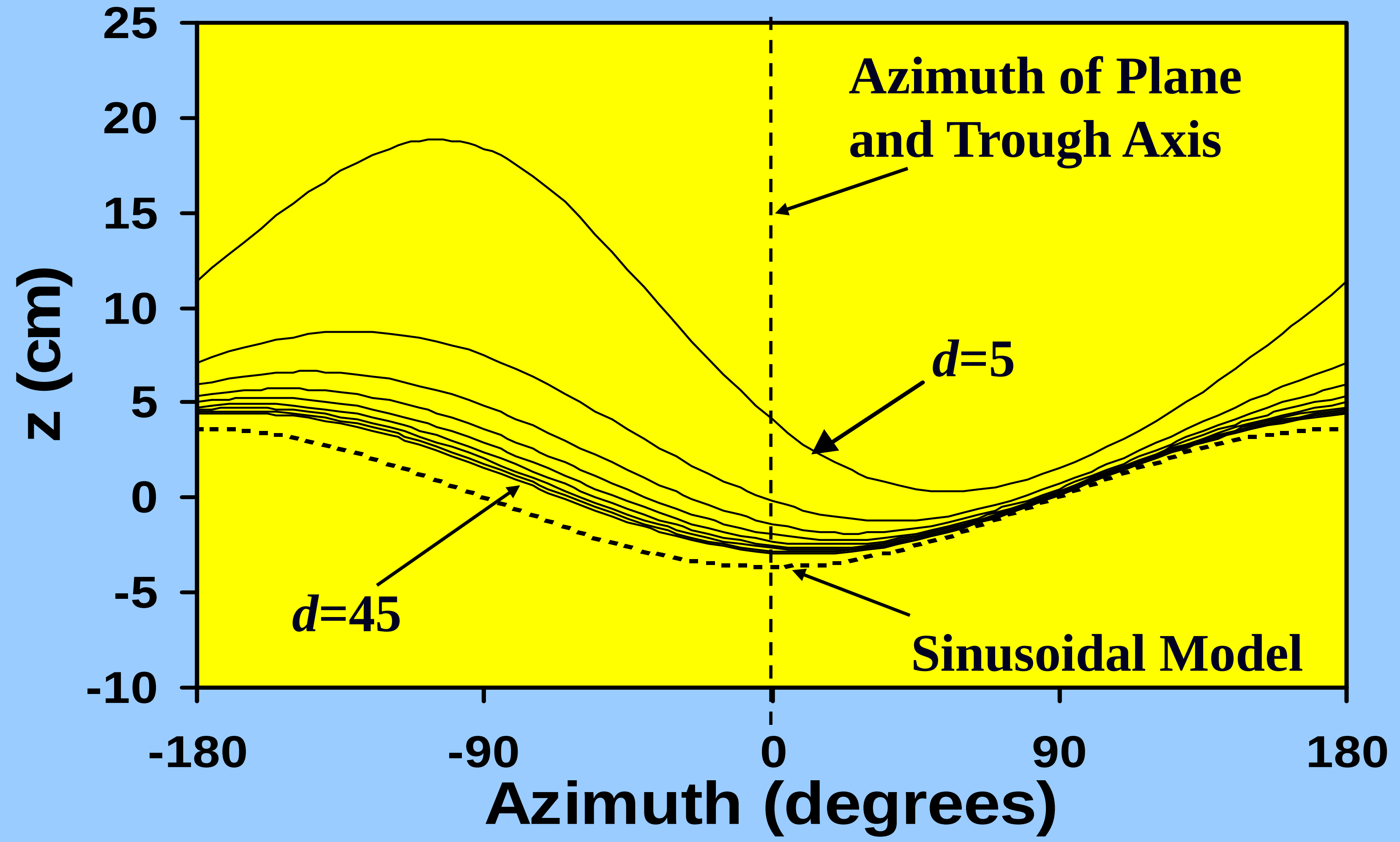


FMI Intersection Curves

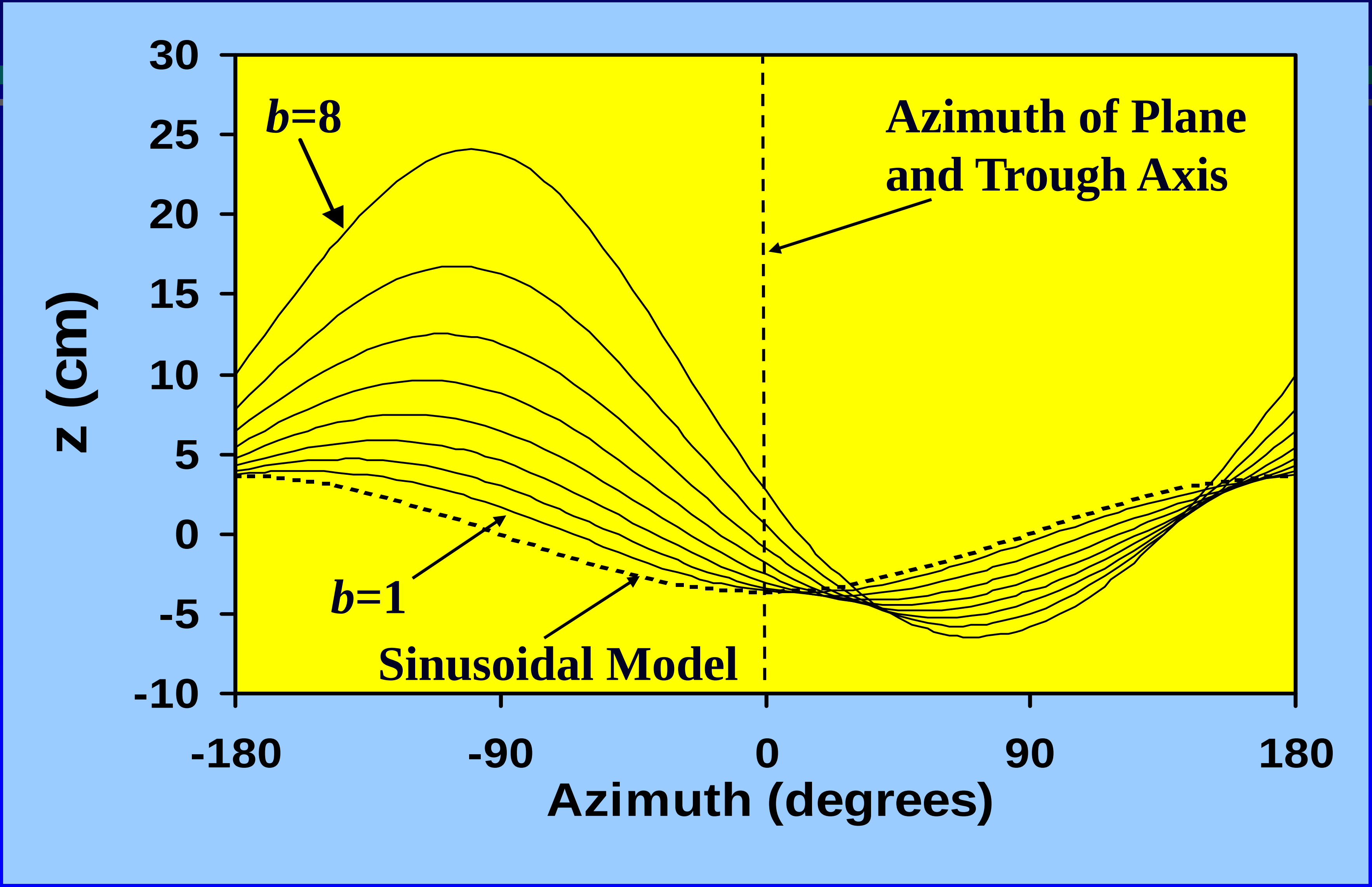




FMI Intersection Curves - Varying d



FMI Intersection Curves - Varying b



Testing the New Model

- 55% Coverage FMI data
- 39 intersection curves
- 50 m of log
- Mixed trough and plane bedding
- Curves picked, digitised and fitted to conventional and new models
- Dip, azimuth, *d*, and *b* derived for each bed
- Statistical tests carried out to determine fit (Durbin-Watson autocorrelation)

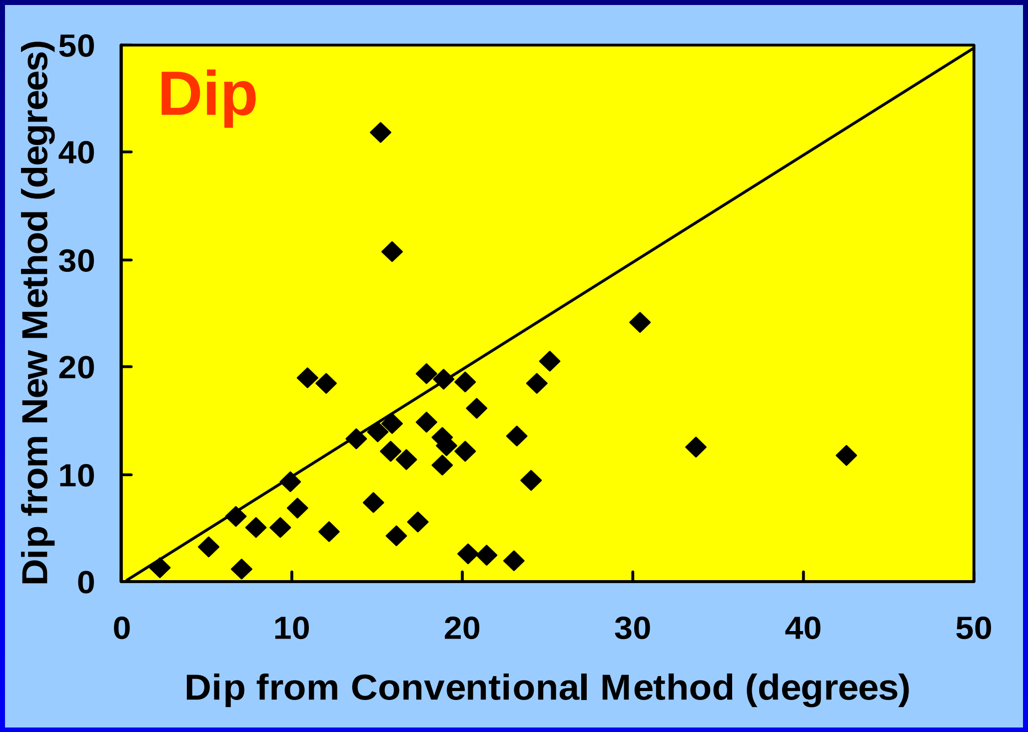
Testing Results I

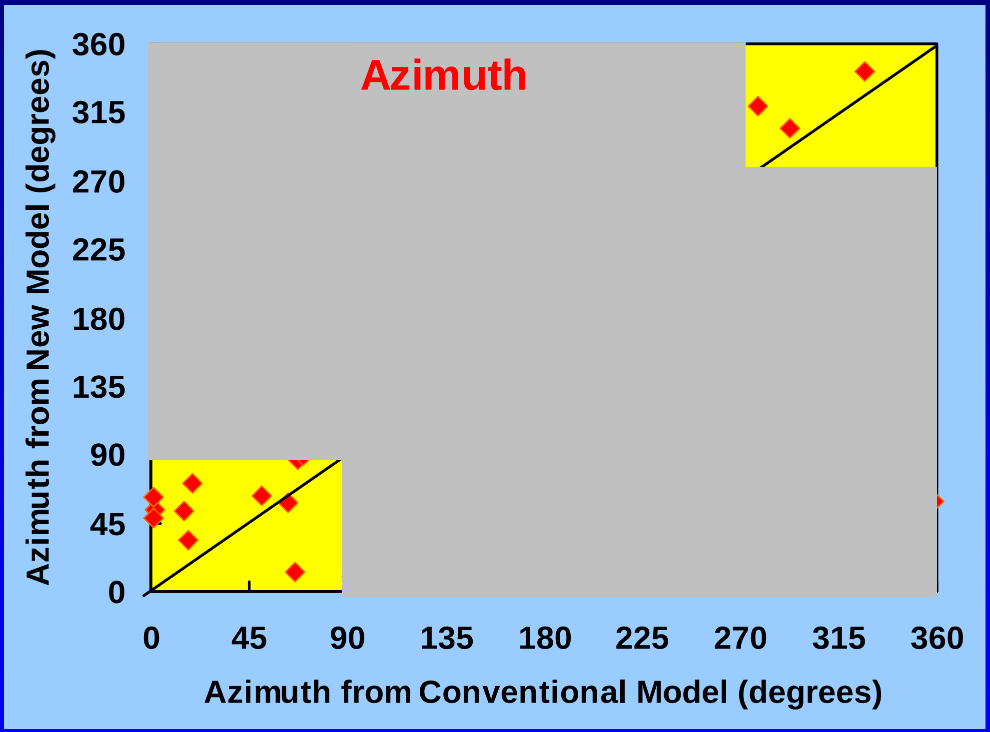
- The new model fitted the data better than the conventional model in the majority of cases

Test	Conventional	New
Sum of Squares	35.4	19.81
Absolute Deviation	0.021	0.015
Adjusted R^2	96.4%	97.9%
Durbin-Watson (<0.8)	0.6631	1.050

Mean values for all 39 curves

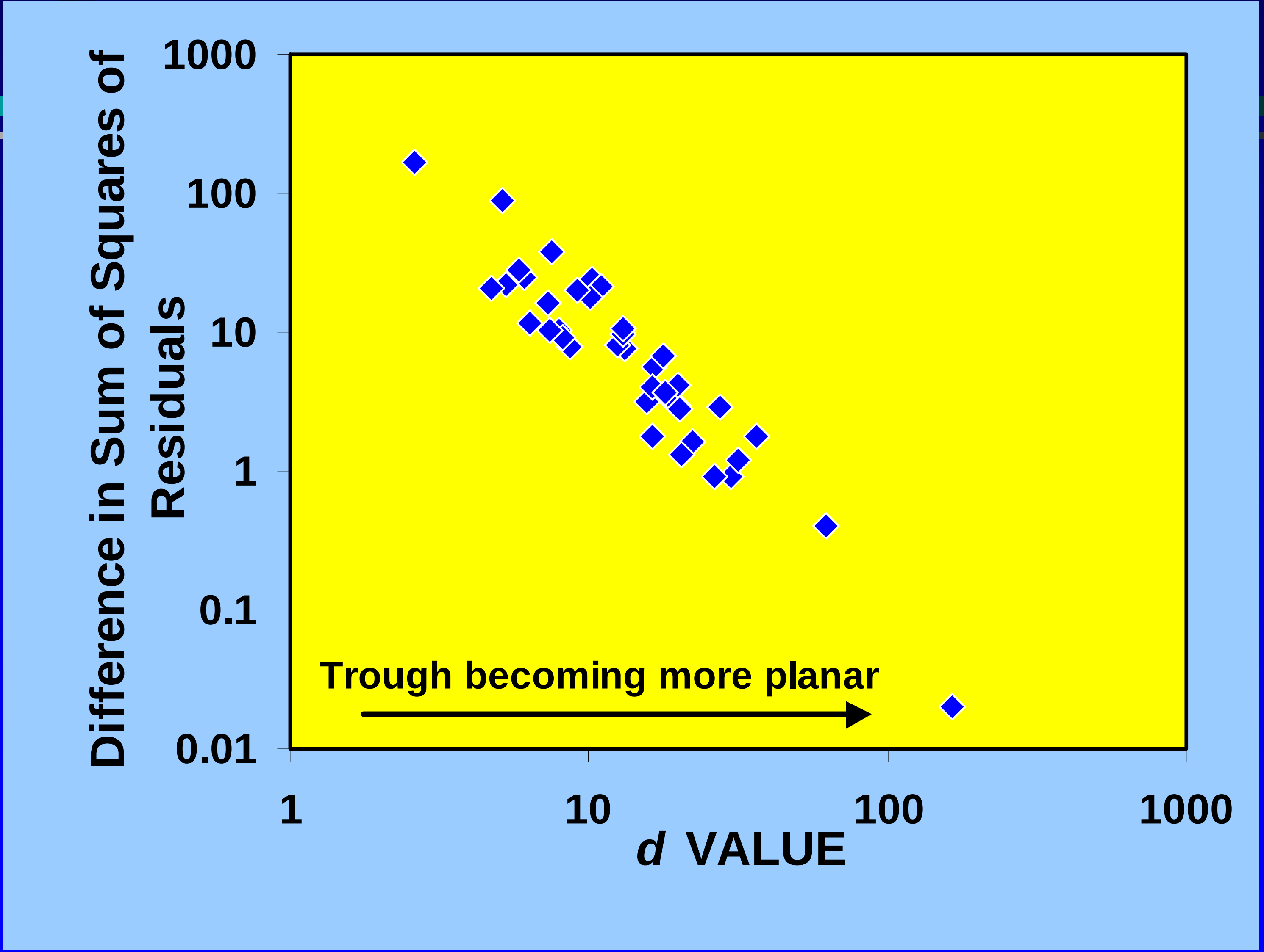
Comparison of Two Methods - Dip and Azimuth





Testing Results II

The difference in the two techniques becomes greater for acute troughs



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 <u>mean dip</u> and <u>mean azimuth</u> for sets of curves spanning a significant vertical interval**
- **The new method provides highly accurate values of <u>dip</u>, <u>azimuth</u>, <u>trough radius</u> and <u>offset</u> for <u>individual structures</u>**
- **This allows them to be mapped uniquely in the sub-surface**

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