How Sedimentological Variations in Carbonate-Cemented Sandstones Affect Seismic Impedance*

By

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Abstract

Our goal is two-fold: (1) to identify the sedimentological variations within carbonate cemented-sandstones and (2) to quantify their effects on P-impedance. To accomplish this goal, we identify the relationship between carbonate cementation and key stratigraphic surfaces, such as the incision surfaces and the flooding surfaces. Next, we use rock-physics models to quantify the impact of sediment parameters on P-wave impedance. We find that the carbonate-cemented sandstones are extremely heterogeneous in nature, even within a depth interval of ~60 meters in our study area at offshore Equatorial Guinea, West Africa. Their grain-size, sorting, mineralogy, clay-content, amount of cement and degree of leaching vary considerably. However, these sedimentological variations can be classified into two distinct clusters in the P-impedance vs. porosity domain. The carbonate-cemented sandstones from the base of incision surface are usually associated with lower shaliness, lower porosity, and higher P-impedance. On the contrary, data from the top of flooding surfaces exhibit higher shaliness, higher porosity, and lower P-impedance. The porosity- impedance trends of the data are quantitatively interpreted using rock-physics models. For example, the constant-cement model with 1% carbonate cement fit the porosity-impedance trends derived using well data. In conclusion, the carbonate cements can be classified into two groups with distinct sedimentological properties, porosity, and seismic impedance. Rock physics models are useful to quantify these sedimentological properties based on porosity-impedance trends.

How Sedimentological Variations in Carbonate-Cemented Sandstones Affect Seismic Impedance

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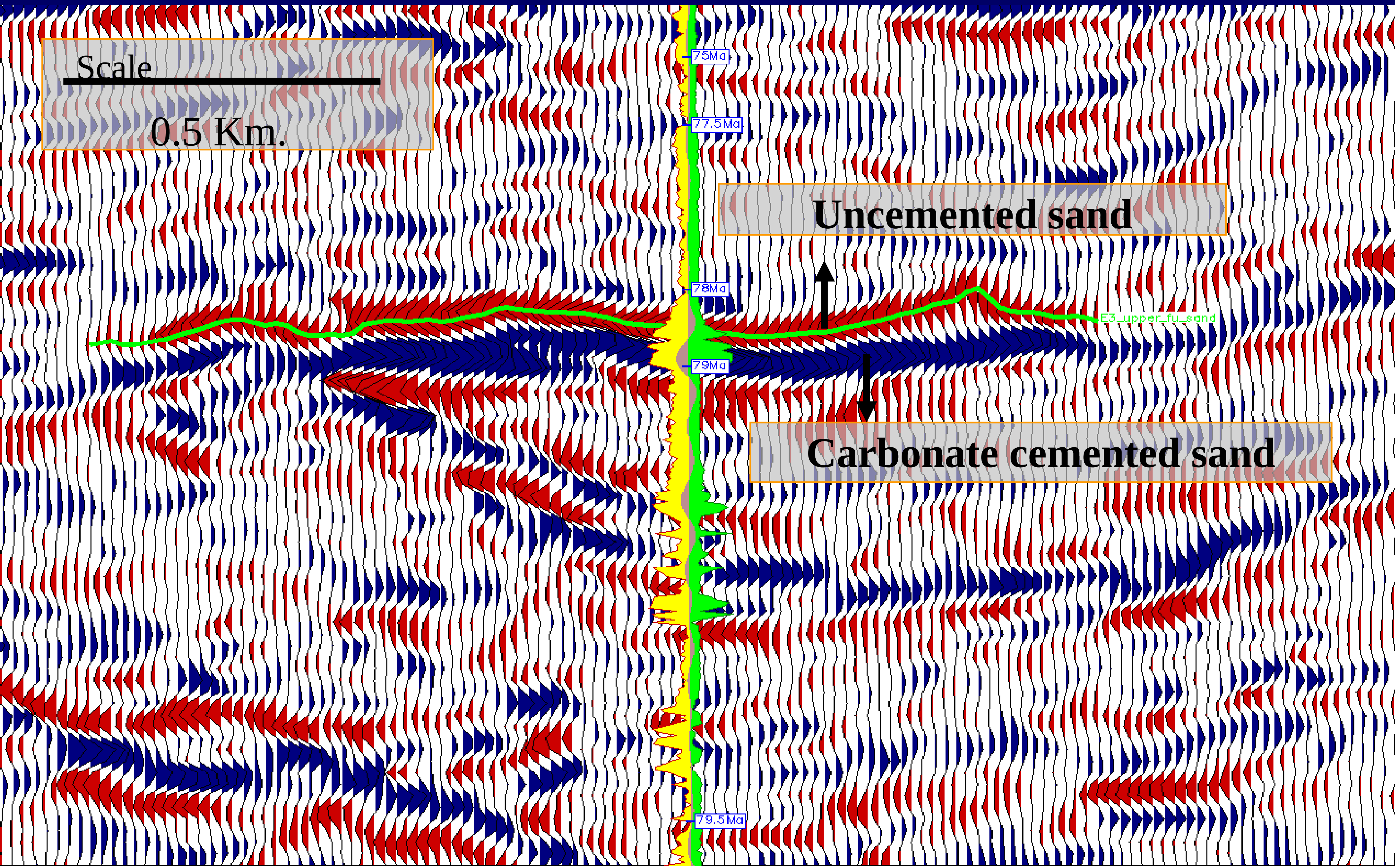
Carbonate cement in deep-water, West Africa



Data Acknowledgement: Hess Corporation

Motivation

Carbonate cementation affects Reservoir quality and Fluid flow.

Sedimentological variations in carbonate cement → **Seismic Impedance**

Objective

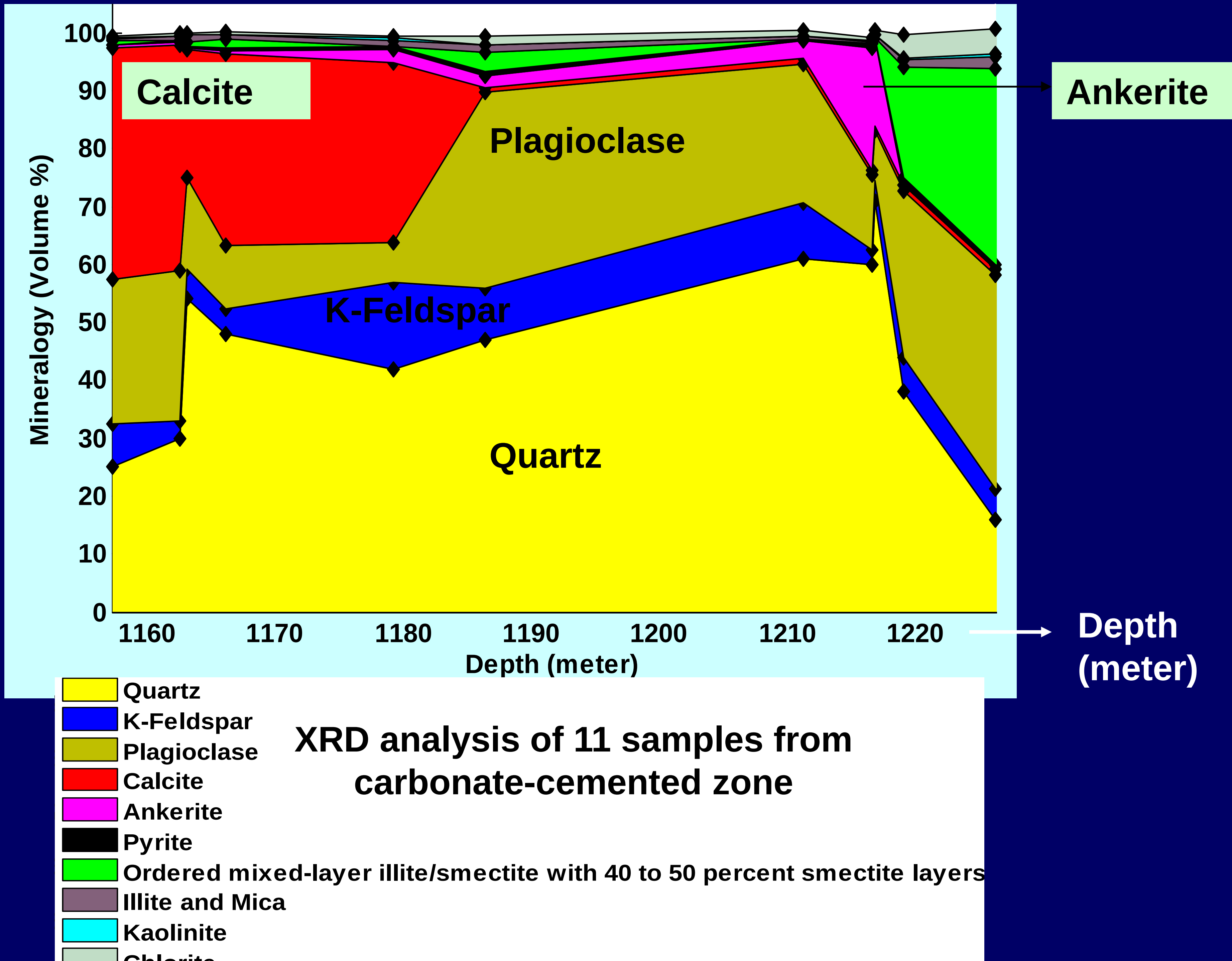
- Identify sedimentological parameters within carbonate-cemented sand interval and their response on Porosity and P-impedance

- Quantify the effects of sediment parameters on P-impedance using Rock Physics model

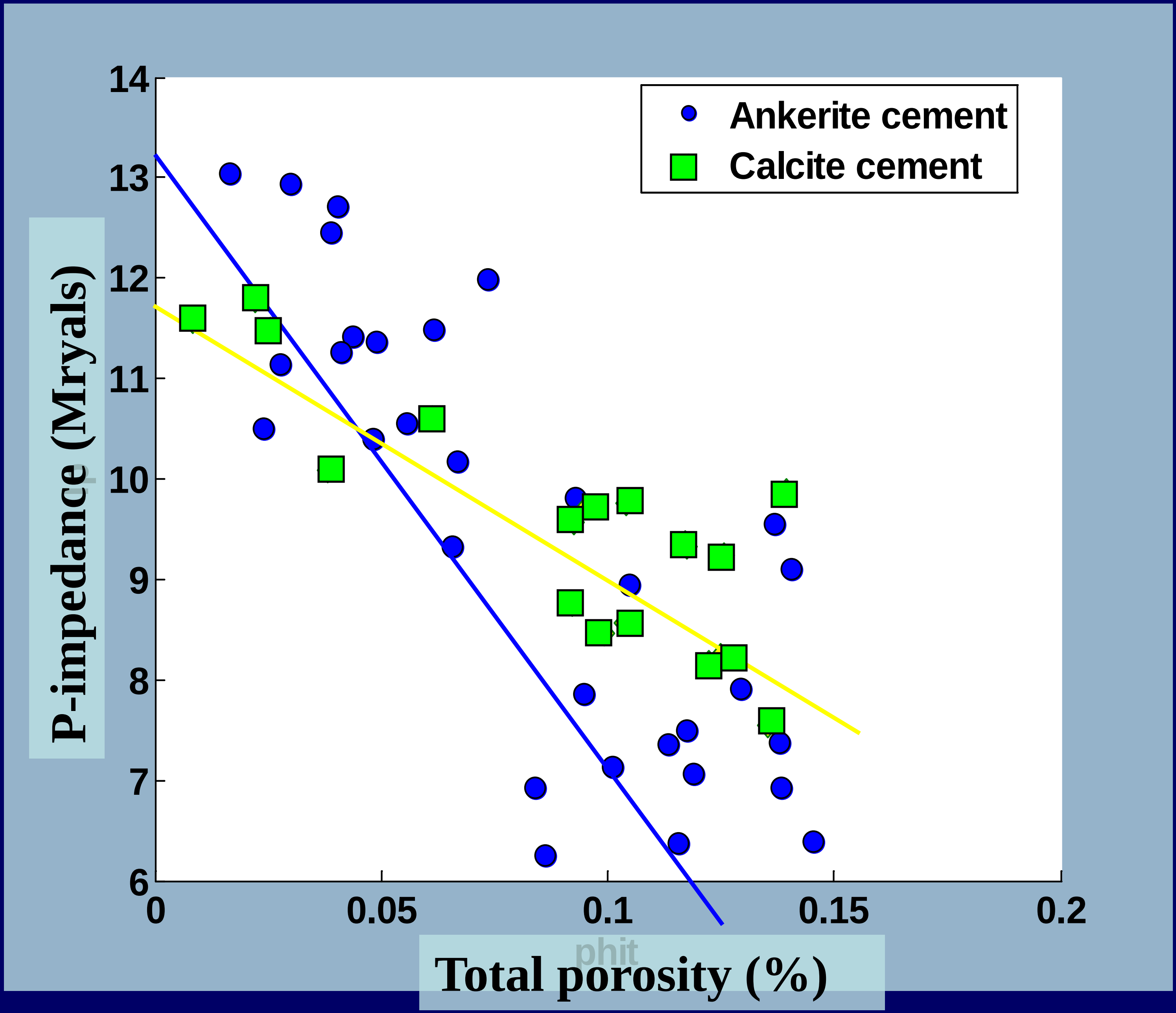
Key sedimentological parameters

- ✓Mineralogy of Cement (Calcite and Ankerite)
- ✓Amount of Cement (2 to 40%)
- ✓ Sorting (sorting coefficient 0.75 to 2.75)
- ✓Clay content

Mineralogy of cement is variable: Calcite to Ankerite

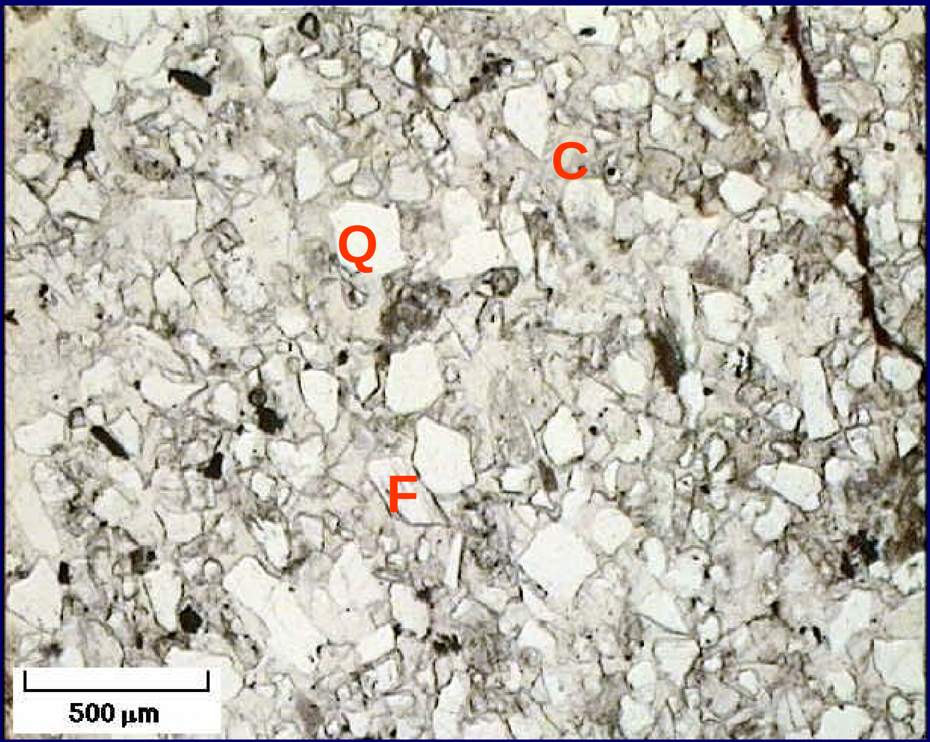


Effects of mineralogy on P-impedance



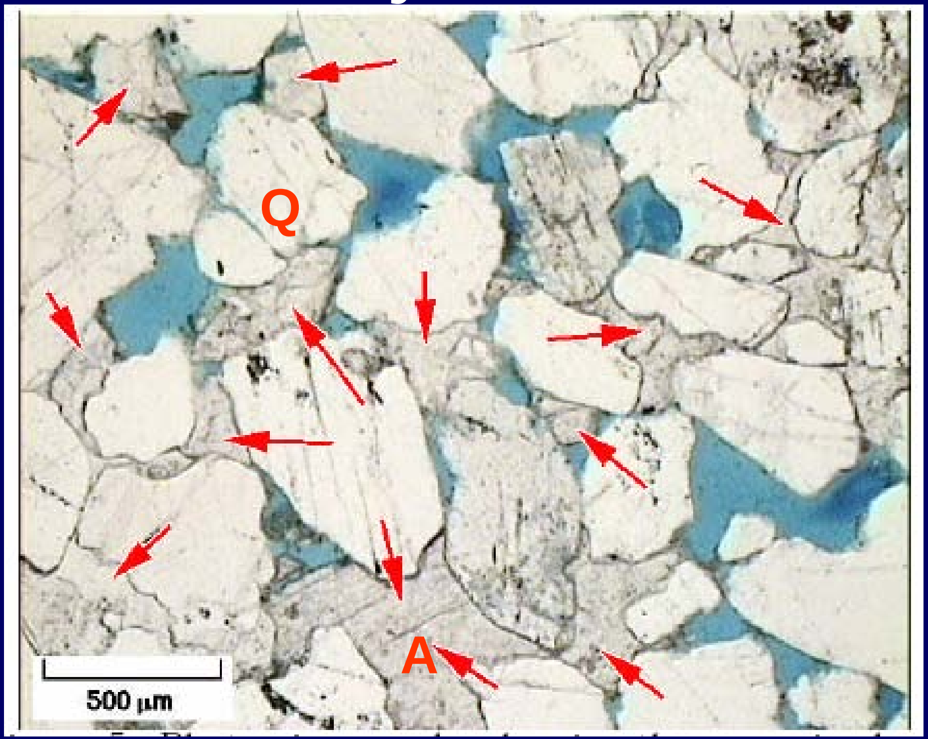
Carbonate diagenesis destroys and enhances porosity

Porosity reduces



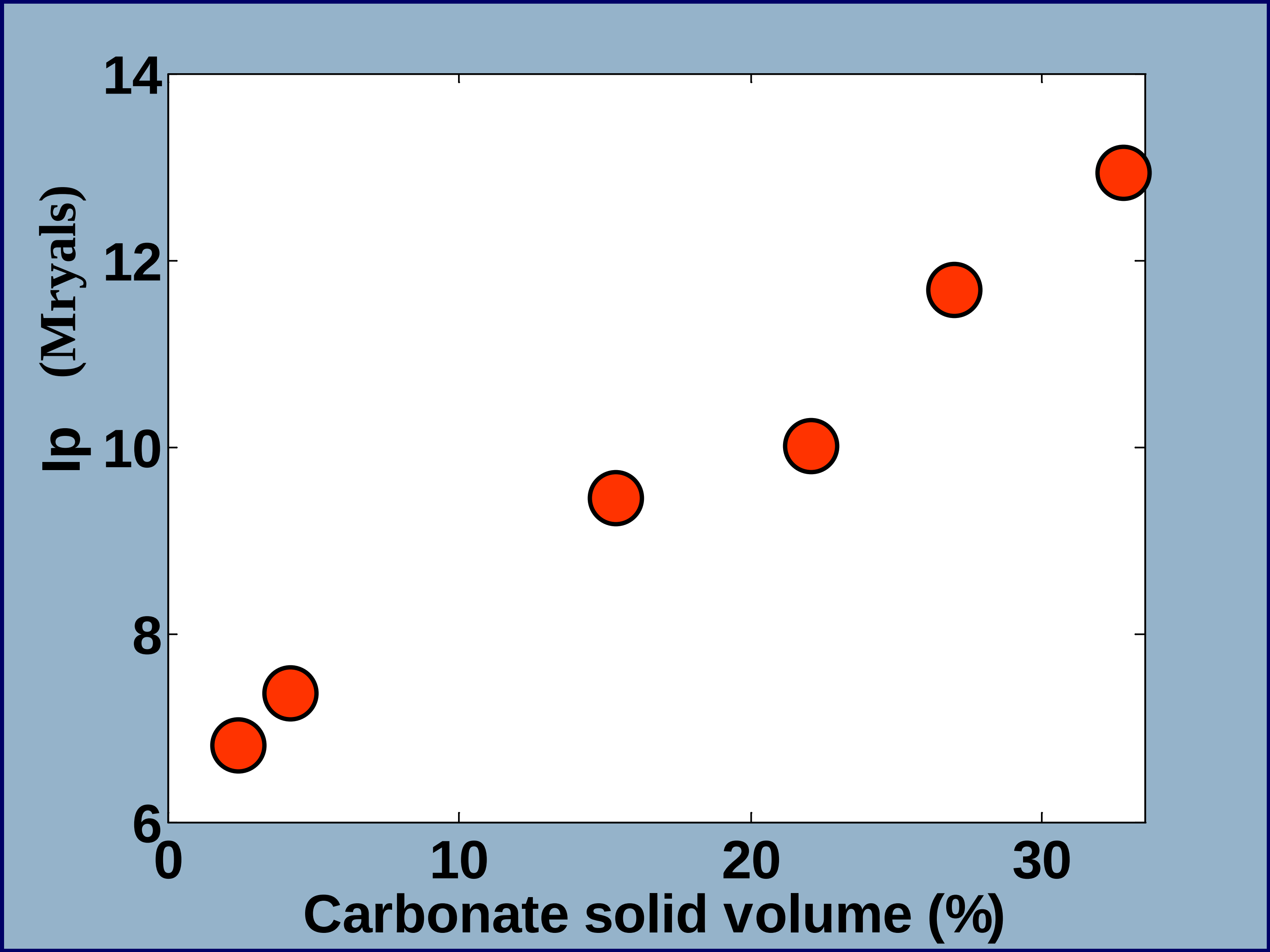
Calcite cement occludes all interparticle pore space
40% calcite

Porosity enhances

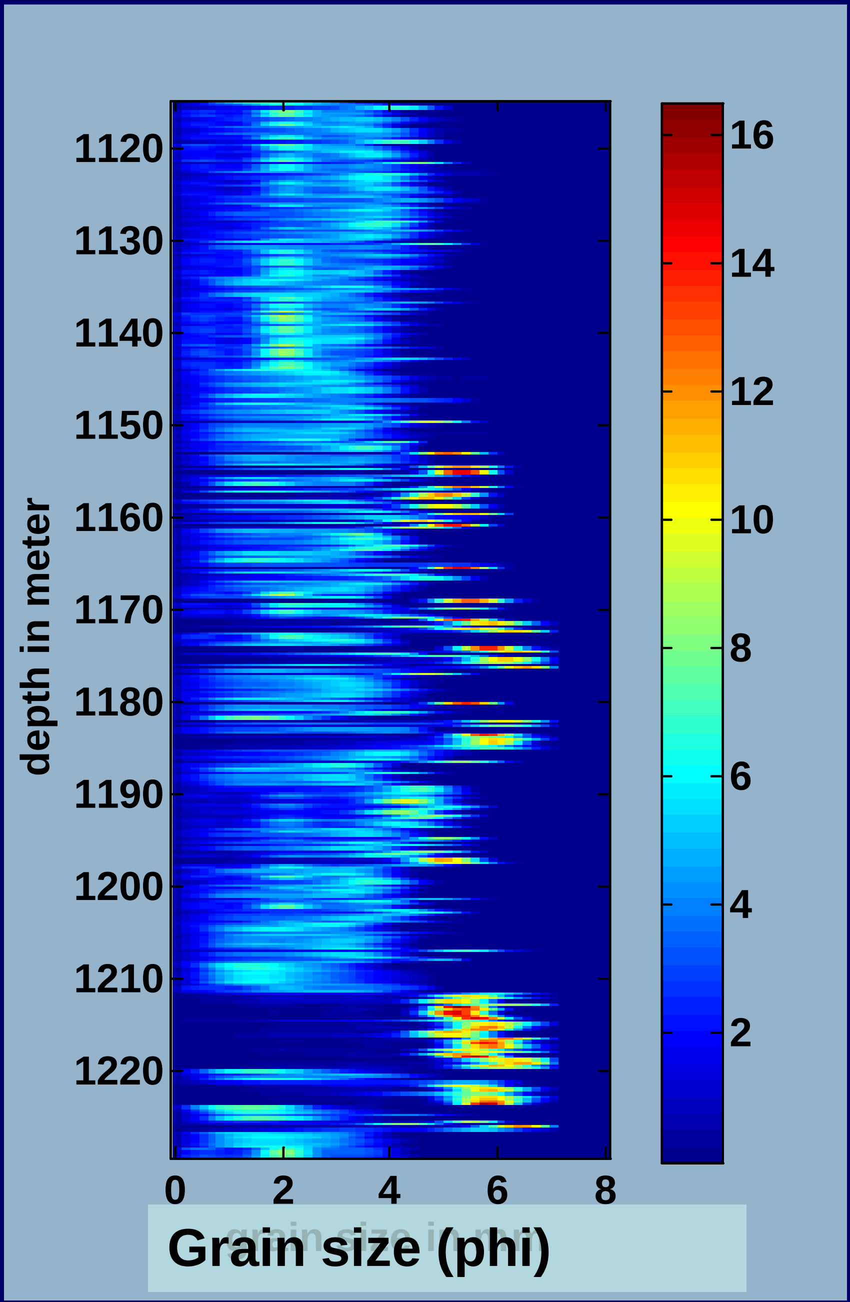


Ankerite cement is more prone to leaching than calcite cement
15% ankerite

P-impedance increase with carbonate-cement volume



Sorting coefficient from grain-size distribution

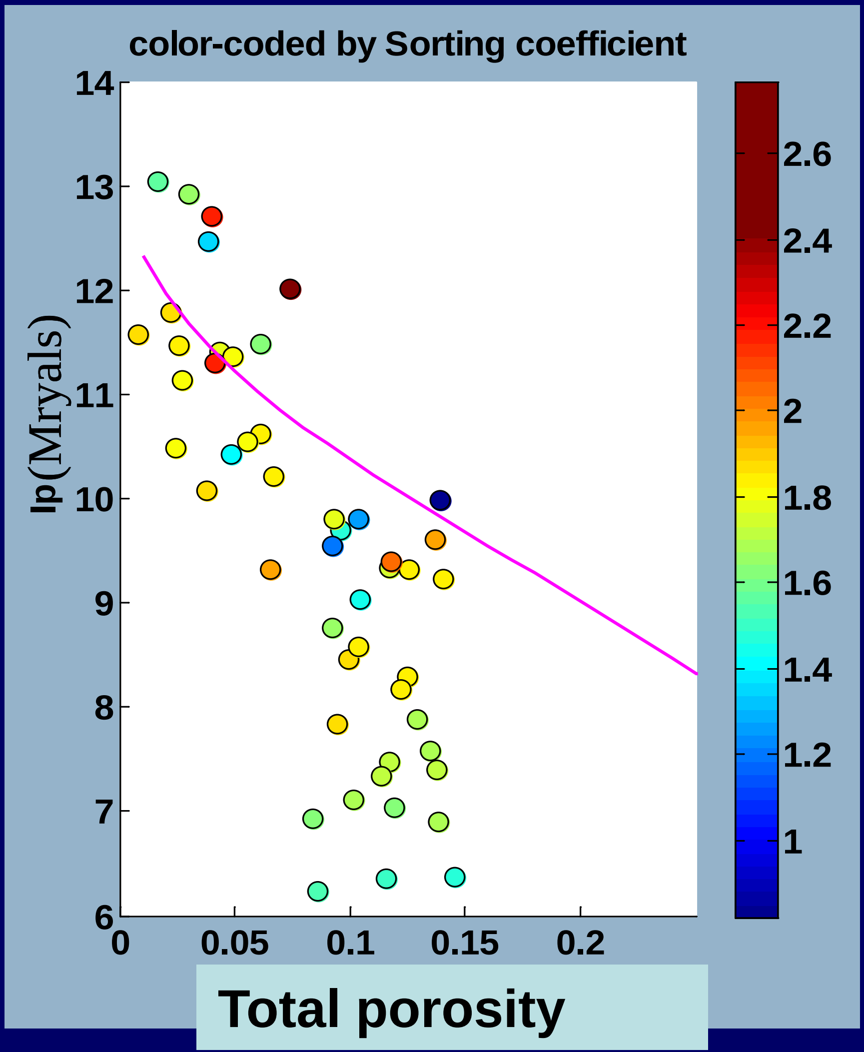


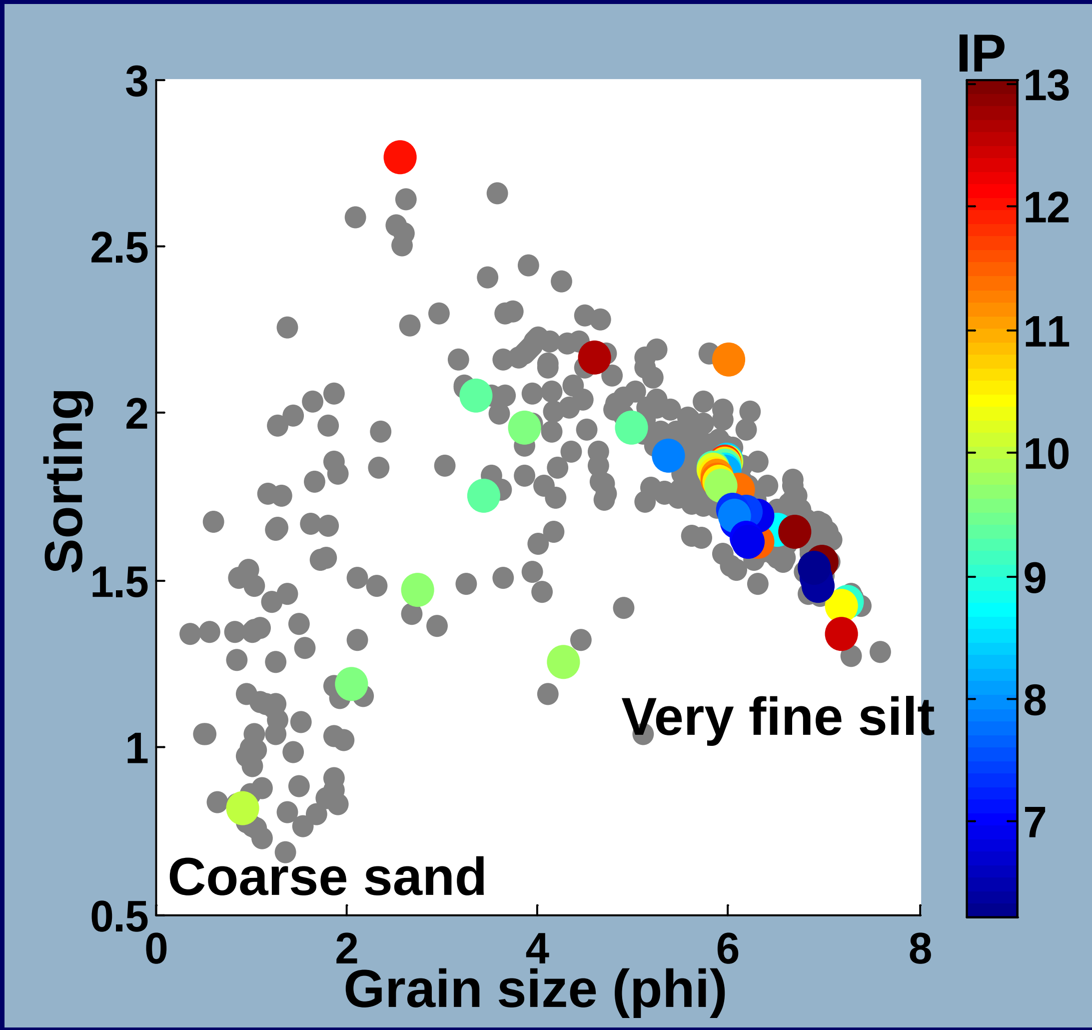
$$Sorting\ \ Coefficient = \frac{P_{84} - P_{16}}{4} + \frac{P_{95} - P_{5}}{6.6}$$

Folk and Ward, 1957

P: percentile of grain size
in the phi-scale

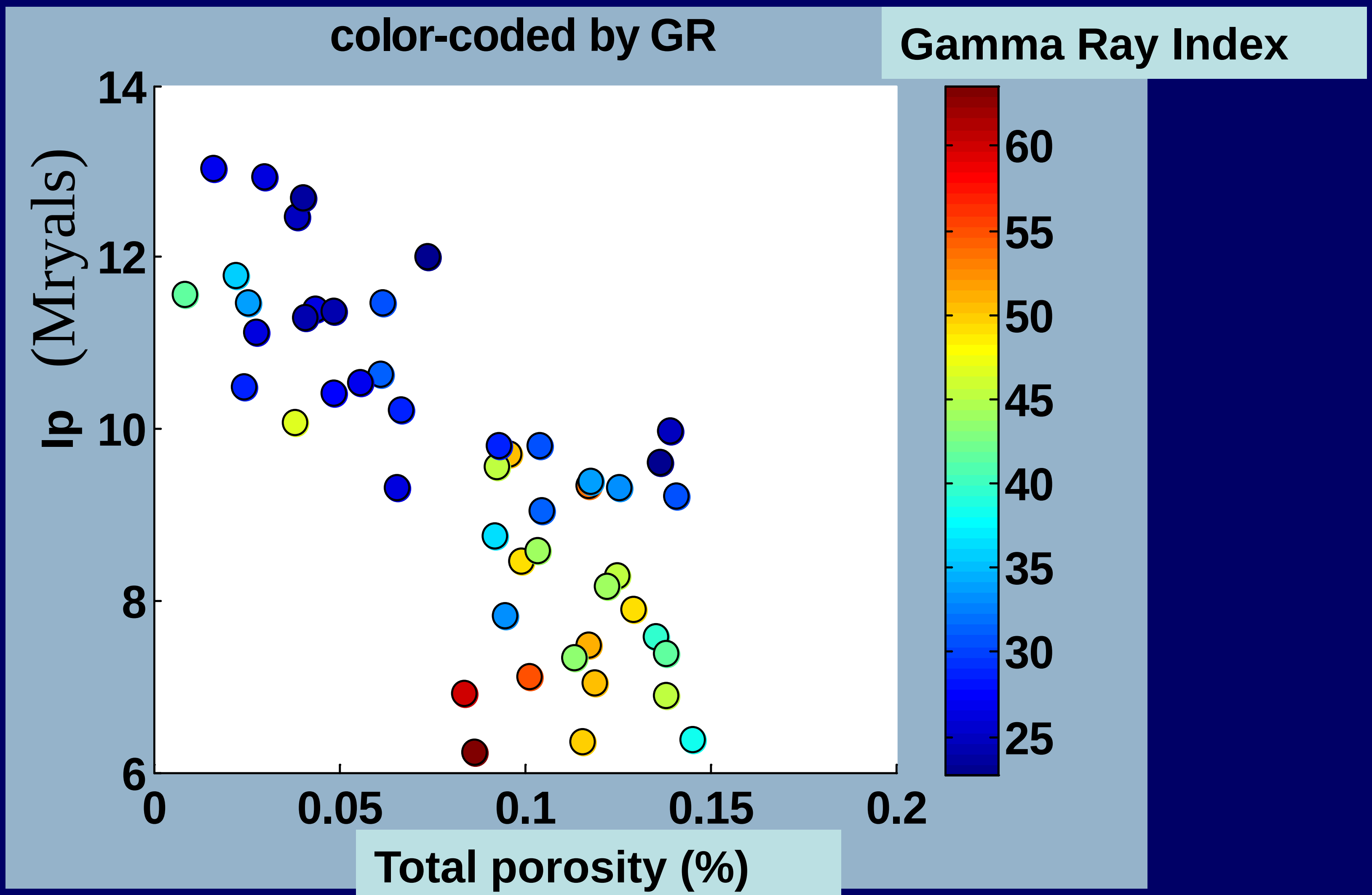
Effect of sorting on porosity and P-impedance



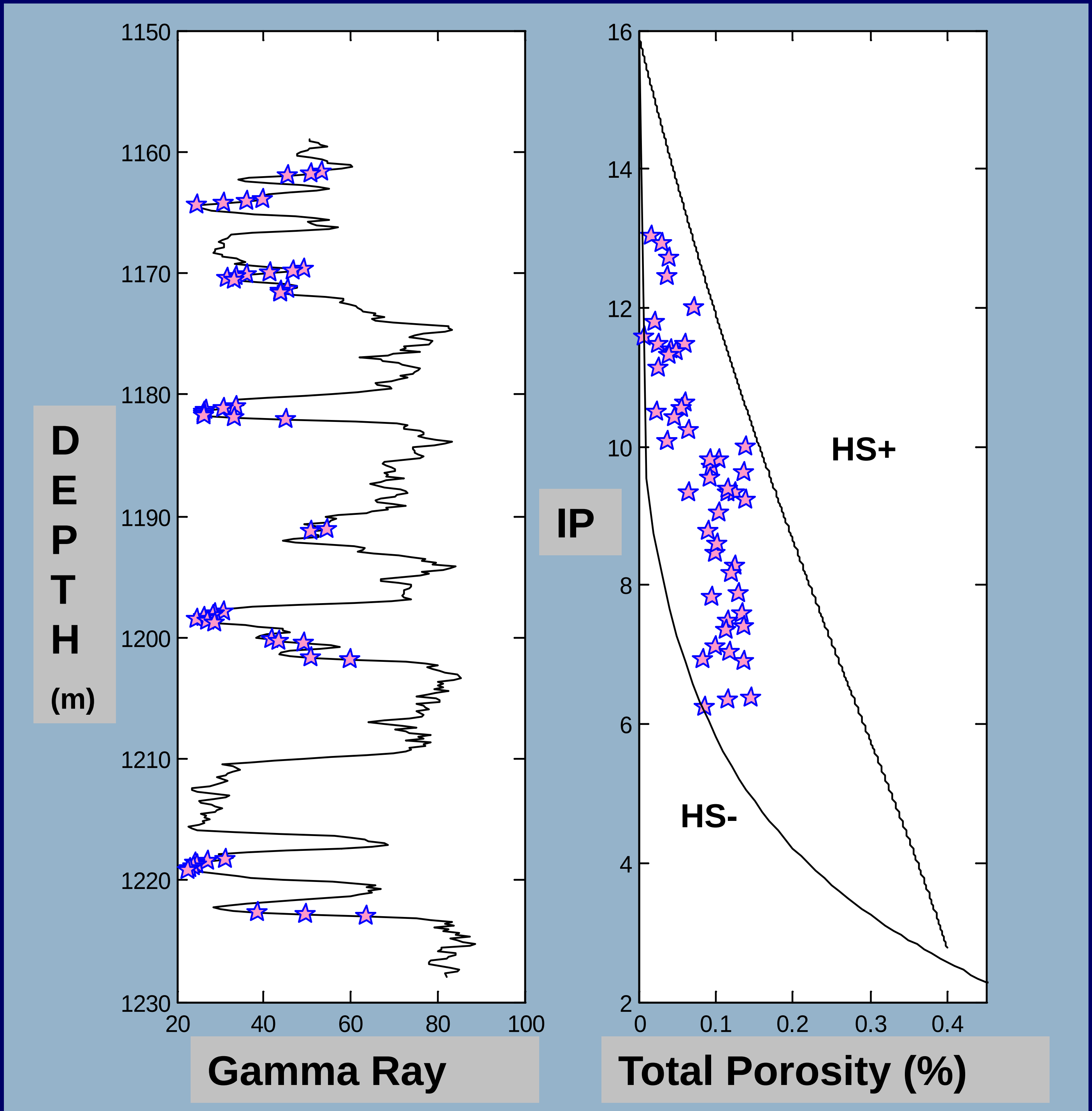


Effects of shaliness on porosity and P-impedance

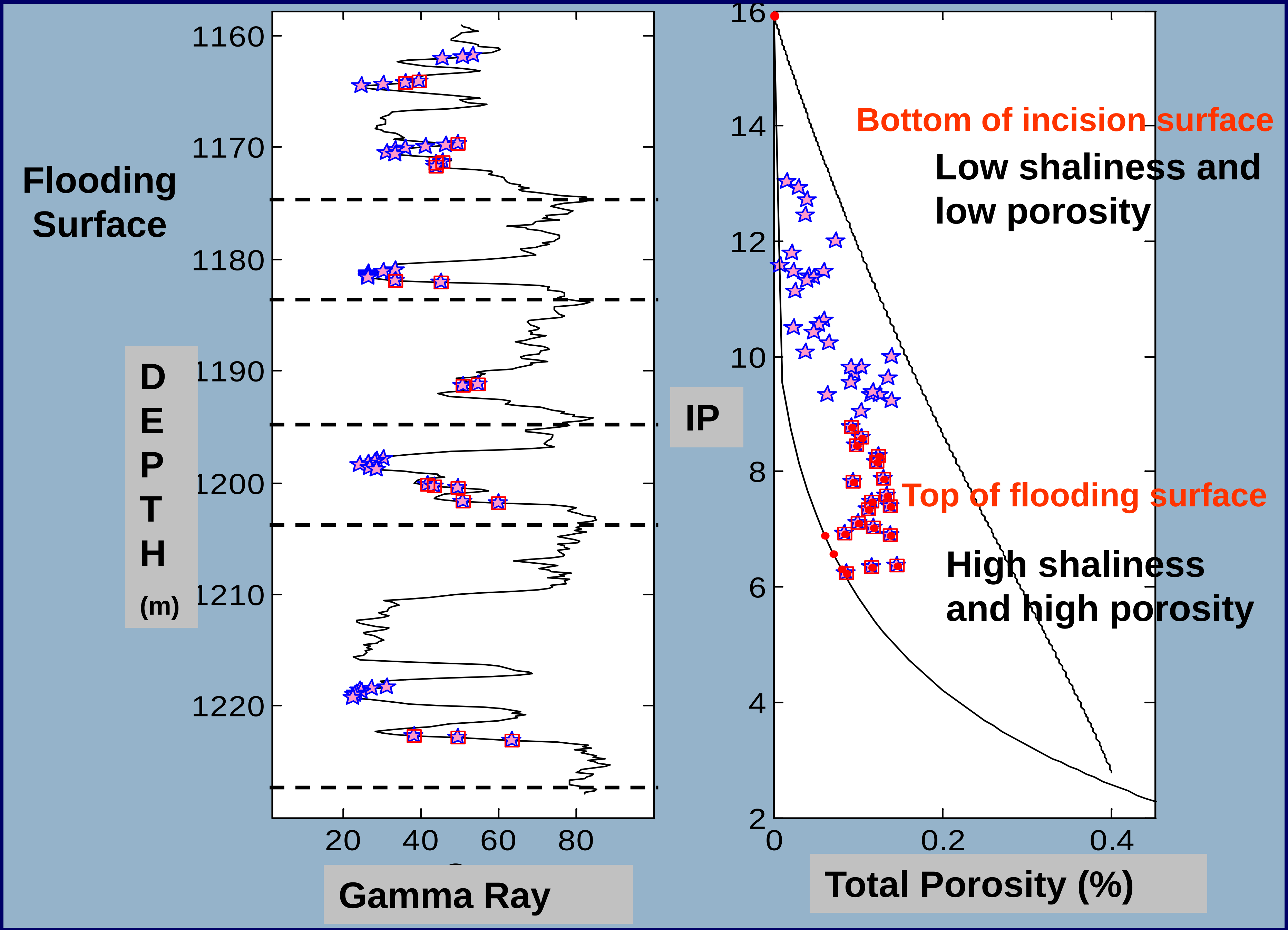
Higher porosity is associated with higher shaliness !



Link between stratigraphic surfaces and carbonate cementation



Stratigraphic surfaces and carbonate cementation



Identification of geological parameters within carbonate-cemented interval significant for *Reservoir Quality*

- ✓Mineralogy of Cement (Calcite and Ankerite)
- ✓Amount of Cement (2 to 40%)
- ✓ Sorting (sorting coefficient 0.75 to 2.75)
- ✓Clay content and relevance to stratigraphic surface

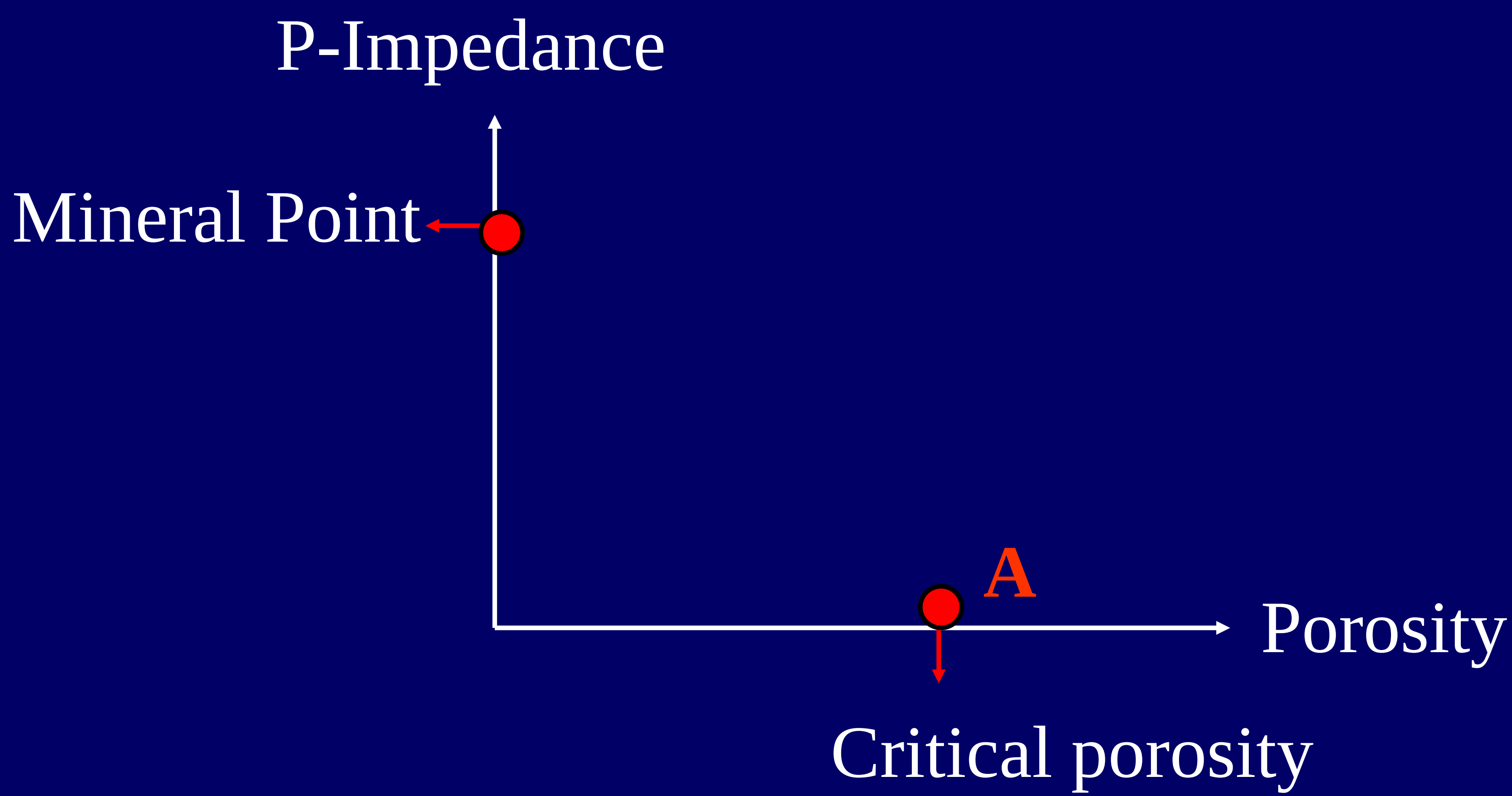
Challenge: Incorporate all these variables in a single Rock Physics Model

Identification of geological parameters within carbonate cemented interval significant for *Seismic Impedance*

- ✓Mineralogy of Cement (Calcite and Ankerite)
- ✓Amount of Cement (2 to 40%)
- ✓ Sorting (sorting coefficient 0.75 to 2.75)
- ✓Clay content

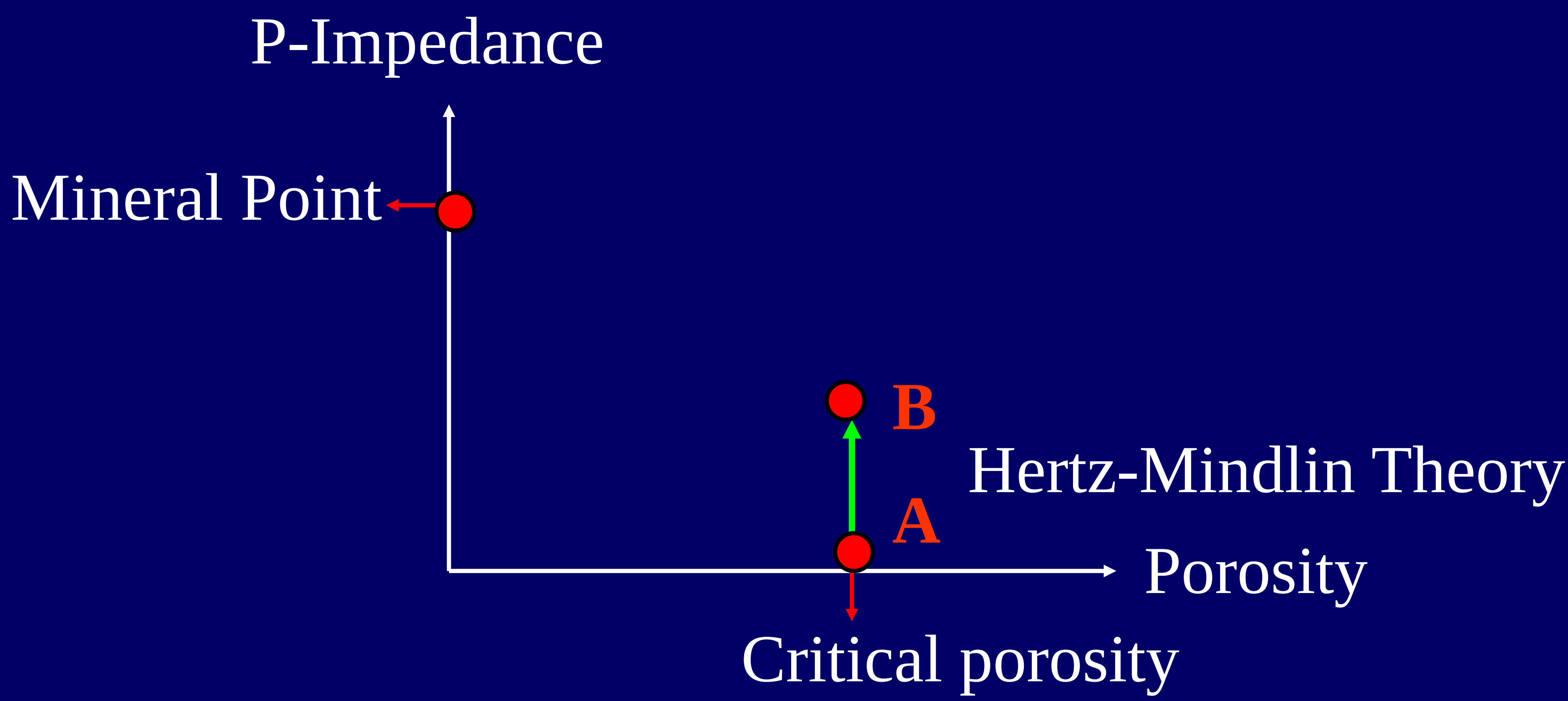
Rock Physics Model for Cemented Sands

Step 1: Identify critical porosity (~15%)



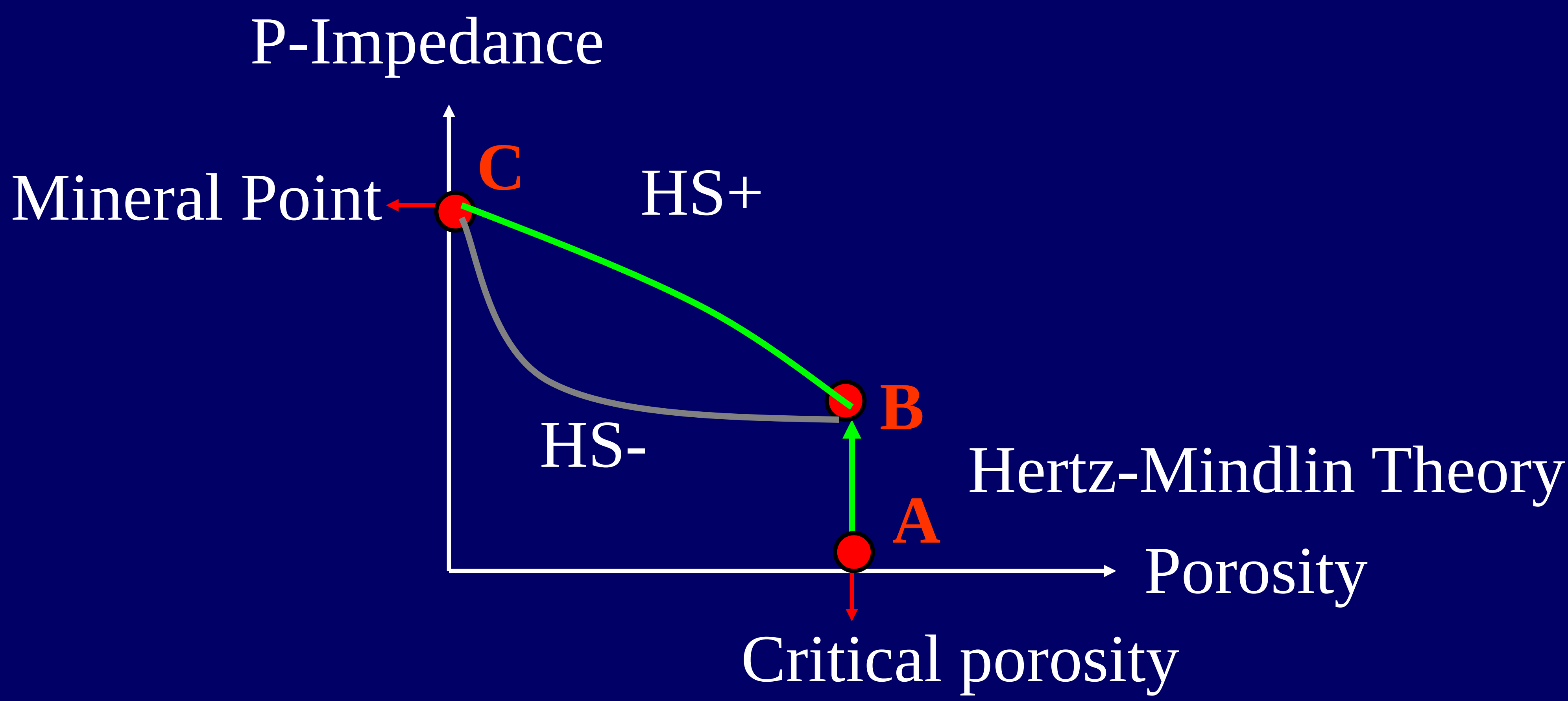
Rock Physics Model for Cemented Sands

Step 2: Compute Impedance at the critical porosity



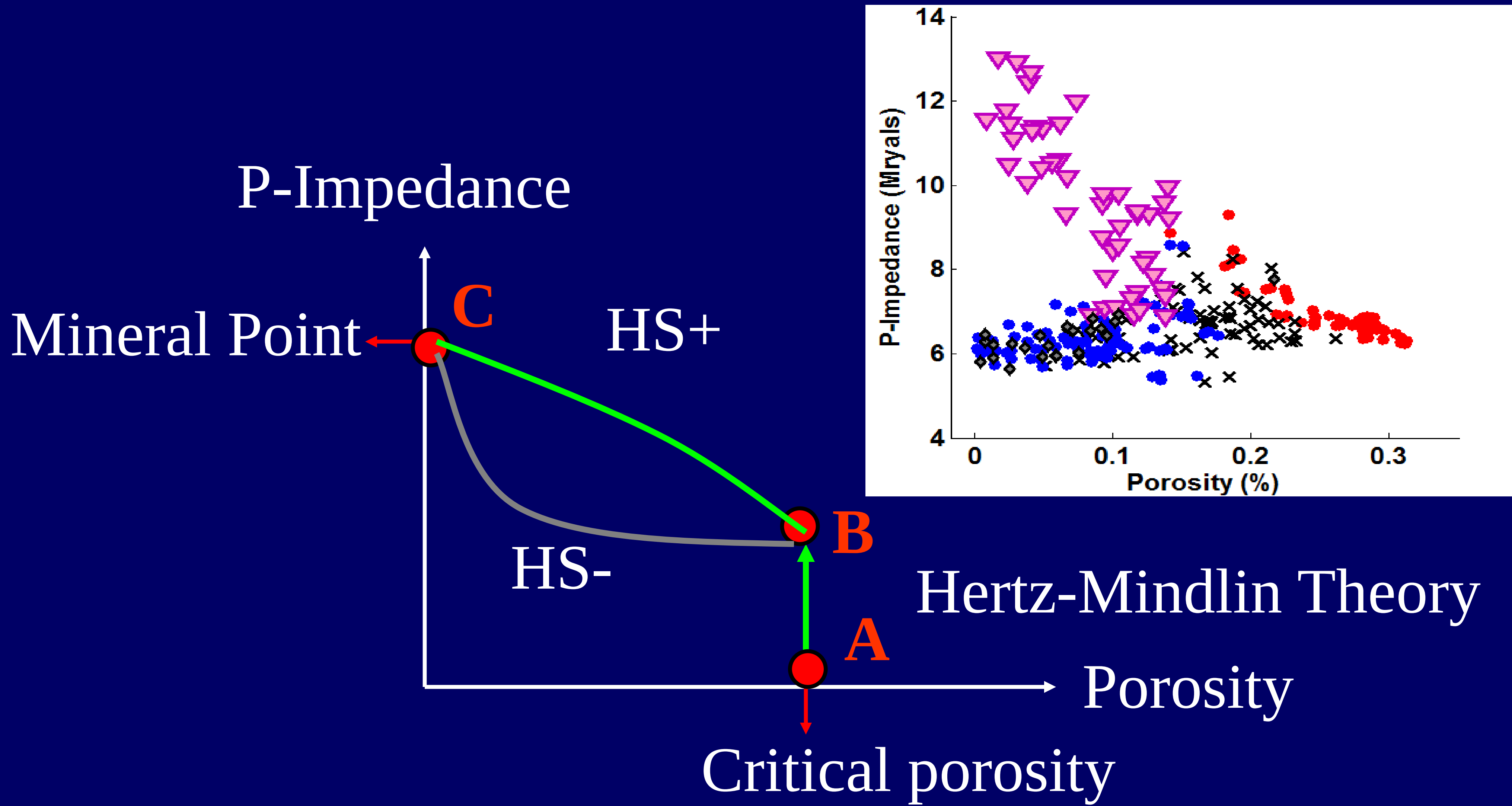
Rock Physics Model for Cemented Sands

Step3: Interpolate using theoretical Upper Bound (Hashin-Shtrikman)

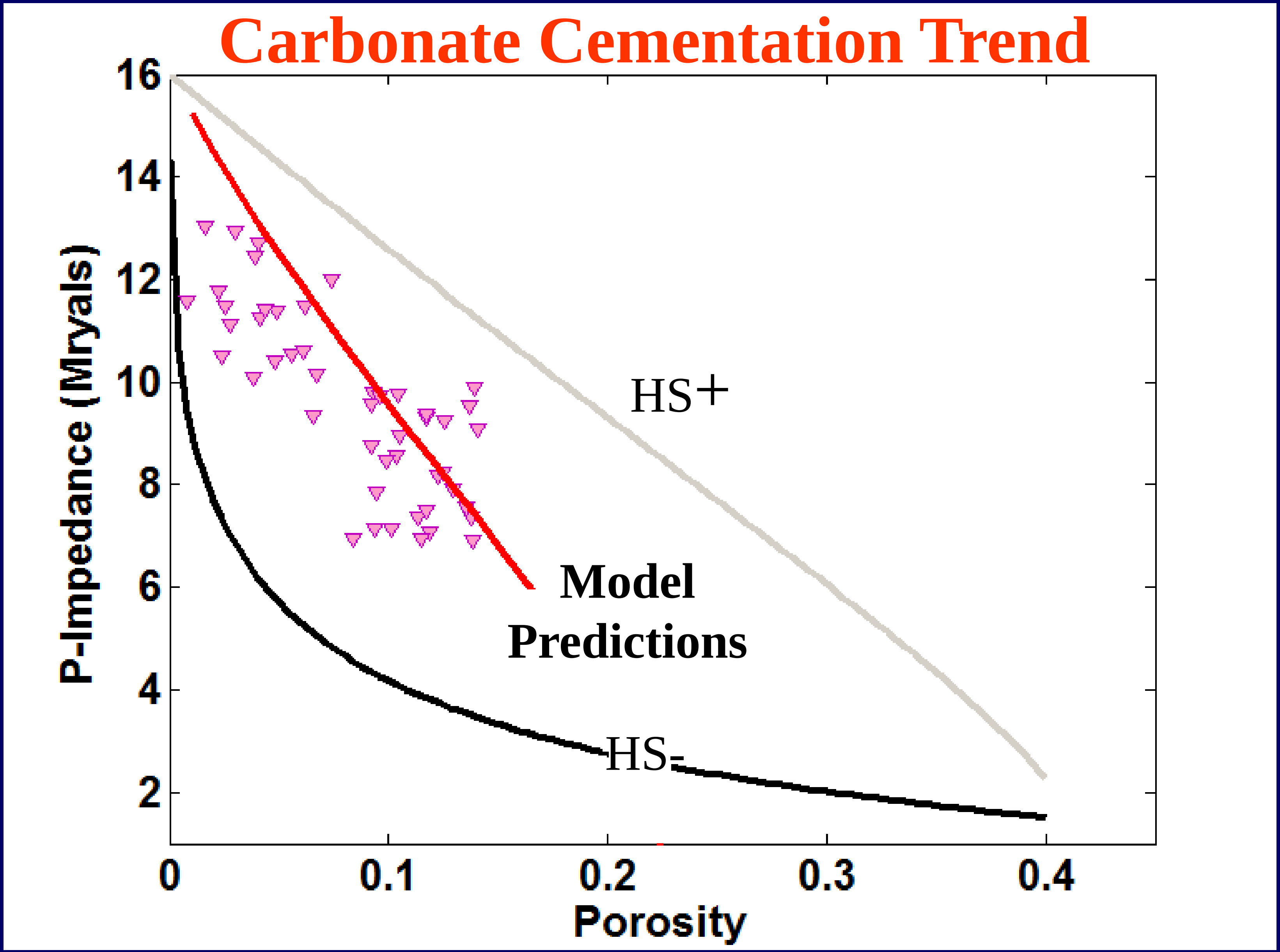


Rock Physics Model for Cemented Sands

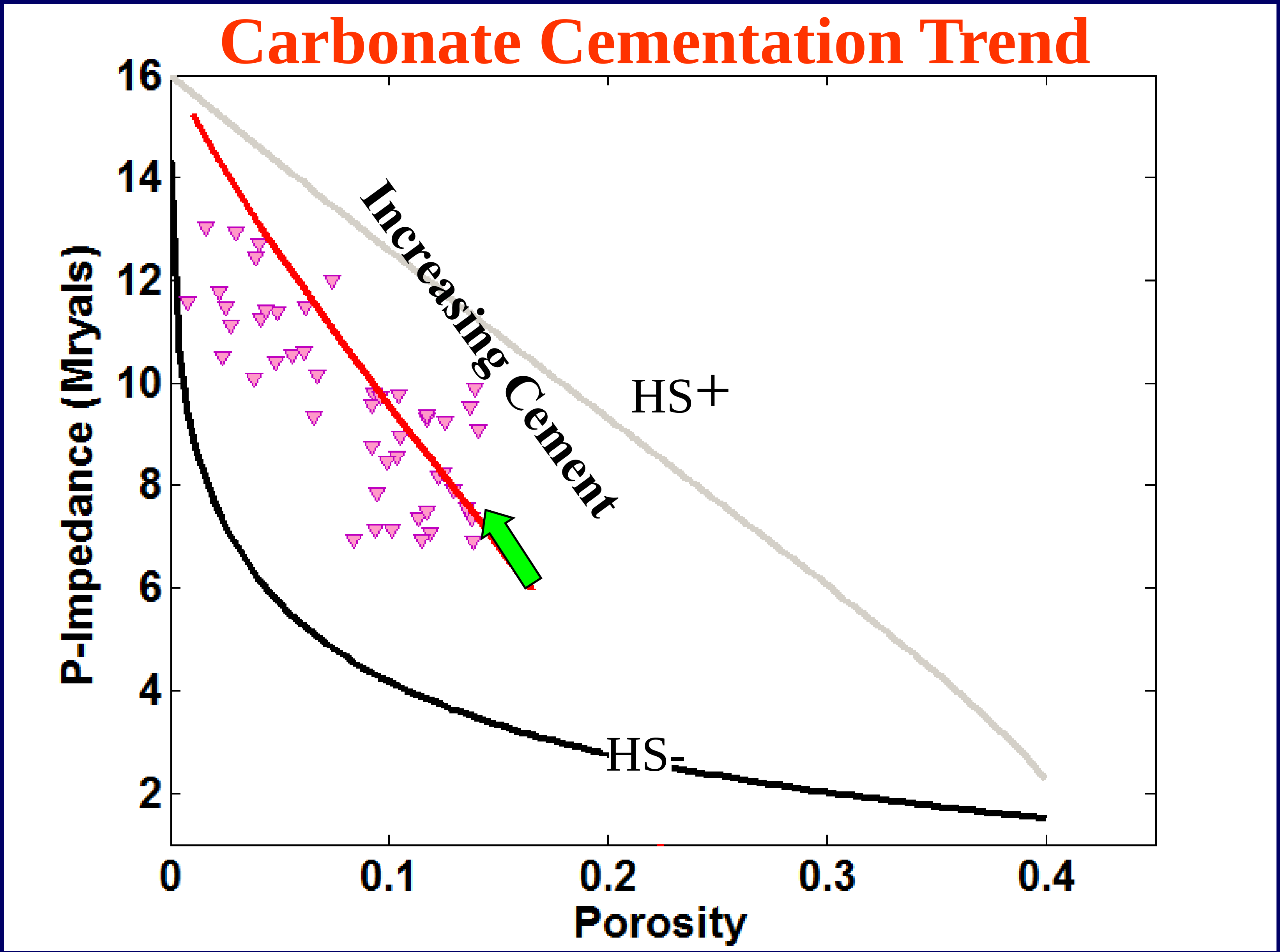
Cementation : *Stiffest* way to add materials in pore-space.



Testing Cemented-sand model with data



Testing Cemented-sand model with data



Conclusion

- ❑ Clusters in impedance-porosity-shaliness crossplot can be linked to key stratigraphic surfaces.

- ❑ Cement volume/ porosity can be quantified from P-impedance using a Rock physics model.

Reference

Folk, R.L., and W.C. Ward, 1957, Brazos River bar: A study of significance of grain size parameters. Journal Sedimentary Petrology, v. 27, p. 3-26.

Thank You.