INFORMATION THEORY AND THE QUALITY OF GEOLOGICAL REASONING

A quantitative model in geology is no better than the foundation of geological reasoning on which it is erected, and a numerical measurement is no better than the method used to obtain it.

Proposition: The measured stratigraphic section is the basis of historical geology and provides the raw material for the reconstruction of past environments.

⇨ The interpretations made are only as good as the observations made and interpreted.

Schwarzacher[1] has applied concepts of Information Theory to studies of the stratigraphic record.

☞ These concepts can be very useful in understanding why and how we gather geologic data, and what we are able to do with it.

One object of this course is to sophisticate your geological reasoning and to develop your data gathering skills.

Schwarzacher has made it very easy to understand where the weaknesses in this system are by applying concepts of Information Theory, based on the Transmission Model.

[1] Walther Schwarzacher, 1975, Sedimentation Models and Quantitative Stratigraphy, QE571.S38

THE GENERAL TRANSMISSION MODEL

If we think of this model in terms of Morse code it is relatively easy to understand.

☞ Because we do the encoding, transmitting, reception, and decoding the messages are usually complete, clean, and easy to understand

But it is easy for *noise* to slip into the system, resulting in a loss of information.

☞ We don't get the full message.

☞ We lose understanding.

THE GEOLOGICAL TRANSMISSION MODEL

The General Transmission Model can be converted into a geological model, as shown on the overhead.

☞ The correspondences between the two model are pretty straight forward.

But what we are interested in are the sources of noise in the geologic information, since the amount of noise determines how well we can interpret the past.

Encoding Noise (Recording Errors)

☞ The response is not unique to the process producing it.

1. For example,

   Sunshine = Shale - simple interpretation
   Rain = Sand - simple interpretation
   Rain/Shine = Silt - message confusing.

2. Or, ambiguous color indicators
   - ⇨ Black shales can be produced in a number of environments, swamps, lagoons, deep water.
   - ⇨ But none of these can be interpreted from the color alone, which just means anoxic.
3. Rapid Environmental Fluctuations, where environmental processes change faster than they can be recorded.

Transmission Noise

☞ Alteration of original sedimentologic data.

1. Lithification
2. Metamorphism
3. Deformation

4. Pressure solution
5. Weathering

Reception Noise - Type I Errors[2]

☞ The point at which human observation enters.

1. Poor Observation
2. Poor recording of Information

Decoding Noise - Type II Errors[3]

☞ Interpreting the right facts in an illogical manner, or in a logical manner from the wrong assumptions. The point at which human Interpretation enters.

1. Lack of understanding of geological processes
2. Lack of understanding of modern environments.
3. Lack of analytical technique.
4. Ignorance.
5. Stupidity.

In general it has been true that the quality of geological interpretation has increased with time.

⇨ Some of this is due to accumulating experience.

⇨ Some is due to more refined observational techniques.

But none of it is any good, if the individual scientist isn't any good.

[2] From Wiley, Phylogenetics, p 113

[3] From Wiley, Phylogenetics, p 113

THE STATE OF GEOLOGY
THE THEORETICAL FRAMEWORK

Plate Tectonics was a revolution in geology.

⇨ To a large extent all the rapid changes geology has been undergoing in the past several decades is a direct result of this paradigm shift.

⇨ It presented a lot of puzzles to solve.

⇨ Was accompanied by an enormous expansion of analytical techniques.

There have been numerous smaller revolutions in each of the subdisciplines, resulting in totally new ways of looking at the earth.

Descriptive Geomorphology	⇨	Process Geomorphology	⇨	Neotectonics and geomorphology

Soft rock geology has been undergoing equally significant changes

⇨ Whole field has been transformed

⇨ Most of what you will learn did not exist 15-20 years ago.

Traditionally, soft rock geology consisted of

⇨ Stratigraphy

⇨ Sedimentation

⇨ Sedimentary petrology

In the past these were taught independently, as ends in themselves.

⇨ It was not always clear what to do with the information

☞ For example, grain size analysis.

⇨ Even less clear how these individual subjects were connected.

Today these subjects are not longer ends in themselves.

⇨ They have become just tools to understand larger, more encompassing theories.

⇨ Thus, there exists a hierarchy of theories in the modern paradigm.

☞ The most encompassing is tectonics.

☞ *Nothing in geology makes sense except in terms of tectonics.*

Basin Analysis

"The integrated study of sedimentary basins as geodynamic entities." (Allen and Allen)

⇨ Each basin has specific igneous, sedimentary, metamorphic, structural, geomorphic features because of the way energy is dissipated.

OVERHEAD: Basin Analysis
OVERHEAD: Creed of the Tectonic Theory of Basin Analysis

Each basin has an ideal filling sequence, assuming:

1. Tectonic development is simple
2. Sea level remains constant.
3. Country rock in which basin develops is uniform.

None of these assumptions are true, necessarily

Question: Can we predict the variations to be expected?

⇨ Only to a limited degree
⇨ Sea level assumption best developed in sequence theory.
⇨ Tectonic assumption.
  ☞ Most natural processes are cyclical, including tectonic ones.
  ☞ Most basin development does not follow ideal equation.

Nonetheless, broad patterns and similarities can be recognized in basin around the world and across time.

⇨ That is what allows us to come up with basin models like those contained in the Wilson cycle.
⇨ And, allows us to predict what the sediments in these basins will look like.