[PS]Students' Conceptions and Misunderstandings About the Core Concepts of Sequence Stratigraphy*

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Search and Discovery Article #70099 (2011)
Posted July 26, 2011

*Adapted from poster presentation at AAPG Annual Convention and Exhibition, Houston, Texas, USA, April 10-13, 2011

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Abstract

We conducted an in-depth assessment of 27 students' content knowledge of the principles of sequence stratigraphy. All students (10 juniors, 15 seniors and 2 graduates) were enrolled in advanced undergraduate stratigraphy courses at three research universities in Midwest U.S. Participants took between 2 and 9 geology courses prior to our study. 60% of students were majoring in geology and 40% in environmental geosciences. 40% of students had 2 or more field-based courses. Data were collected over 3 semesters, and included semi-structured research interviews, spatial visualization tests, classroom observations, and embedded lab assignments. Using constant comparative analysis, we documented students' conceptions of principles such as eustasy, base level, accommodation, depositional sequence, and sequence boundaries. From these data we developed assertions about the nature of student comprehension of this material and mapped conceptual connections and conceptual change as a result of instruction.

Results indicated that 60% of students poorly integrated tectonics, climate and time in their sequence stratigraphic models. 70% were unable to correctly predict the response of carbonate margins to sea level fluctuations, and had a misconceived or absent notion of base level. 80% of participants had a poor grasp of time scales associated with different depositional sequences and flooding surfaces. Problems were also observed with recognizing unconformities in the field and distinguishing the origin of accommodation space. Our data also suggested that terminology prevented proper scaffolding of concepts during learning, and that time in profession may not be a good predictor of mastery of these concepts or terms. In addition students' spatial skills seemed to correlate loosely with students' ability to understand sediment deposition and distribution in response to sea level fluctuations. We completed a preliminary differentiation among a true alternate conceptions, misunderstandings and instructional bias. For example, the balance between understanding based on physical sedimentology vs integrated sequence concepts as being related to instructional emphasis and past field experience. Post course analysis of a subsample suggested that a successful conceptual change was possible; students were able

to correlate depositional environments and cyclicity. However, some alternative conceptions persisted (e.g. the concept of eustasy and base level remained elusive).

References

Catuneanu, O., 2006, Principles of sequence stratigraphy: Elsevier, Amsterdam, 375 p.

Coe, A.L., D.W. Boescence, K.D. Church, S.S. Flint, J.A. Howell, and R.C. Wilson, 2005, The sedimentary record of the sea-level change: The Open University, Cambridge: Cambridge University Press, 285 p.

Corbin, J.M., and A.L. Strauss, 2008, Basics of qualitative research: Techniques and Procedures for developing grounded theory: Sage Publications, Los Angeles, California, 379 p.

Holbrook, J., R.G. Scott, and F. Oboh-Ikuenobe, 2006, Base-level buffer and buttresses: A model for upstream versus downstream control on fluvial geometry and architecture within sequences: JSR, 76/1, p. 162-174.

Kendall, Ch. G. St. C., G.L. Whittle, R. Ehrlich, P. Moore, R. Cannon, and, D.R. Hellmann, 1993, Computer sedimentary simulation models sequence stratigraphy: Oil & Gas Journal, v. 91, p. 46-51.

Kendall, Ch. G .St. C., P. Moore, G. Whittle, and R. Cannon, 1992, A challenge: is it possible to determine eustasy and does it matter? *in* R.H. Dott, Jr., (ed.), Eustasy: the historical ups and downs of a major geological concept: GSA Memoir 180, p. 93-107.

Posamentier H.W., and P. Weimer, 1993, (eds.), Siliciclastic sequence stratigraphy and petroleum geology—Where to From Here? AAPG Bulletin, v. 77/5, p. 731-742.

Sumner, D.Y., 2003, Intuitive sequence stratigraphy; replacing lectures with inquiry-based computer labs: GSA Abstracts with Programs, v. 35 p. 363-364.

Wandersee, J.H., J.J. Mintzes, and J.D. Novak, 1994, Research on alternative conceptions in science *in* D.L. Gabel (ed.), Handbook of research on science teaching and learning: A project of the National Science Teachers Associations: Macmillan Publishing Company, New York. p. 177-210.

Weimer, P., and H.W. Posamentier, 1993, (eds.), Siliciclastic Sequence Stratigraphy: Recent Developments and Applications: AAPG Memoir 58, 492 p.

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SUMMARY

Background

* Sequence stratigraphy is a useful tool in understanding hydrocarbon prospects, reservoir characterization and academic research on depositional systems.
* Competing terminology (acronyms & jargon) and technical diagrams act as barriers to an intuitive understanding of the basic concepts (Sumner 2003).
* Different model-driven interpretations and methodologies in the literature make diffult the teaching/learning of sequence stratigraphy.
* Few innovative teaching methods exist but, they are not formally evaluated for learning outcomes or effectiveness.
* Undergraduates typically have few field-based experiences.
* There is not a concept inventory in the literature that assess student’s understanding about interactions between sea-level changes and sedimentary processes.
* Spatial thinking is central to understanding sequence stratigraphy.

Objective

* Formal assessment of students’ learning of basic principles: **Eustasy, Relative sea-level, Base level, Accommodation, Sequence, Sequence Boundaries.**

Major Findings

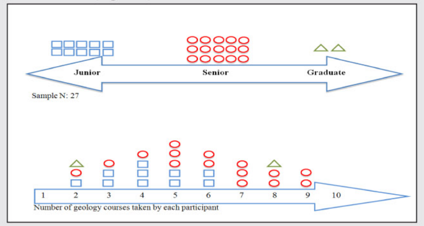
* The concepts of eustasy and base level remain highly elusive.
* Subsidence is not integrated in the student’s conceptions about accommodation.
* Temporal scales associated with relative sea level changes and sytem tracts are misunderstood

Implications

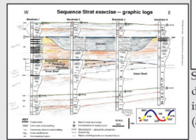
* Diagnosing conceptions & misunderstandings about sequence stratigraphic principles among students and profesional trainees will improve instruction in oil companies and academia through better targeted curricular strategies.

RESEARCH DESIGN

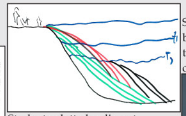
27 students (male and female), majors: 13 geology, 12 environmental geology, Msc:1geophysics,1geology
3 mid-west research-intensive universities.
1 semester of data collection per University.
1 Sed/Strat Senior level course (e.g. 474)



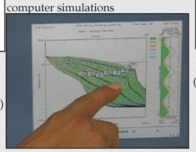
Constant comparative analysis of: lab assignments, class room observations, drawings, performance tasks, visualization tests, individual interviews.



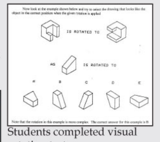
Students completed lab assignments



Students plotted sediment distribution at different time intervals (assessing the concept of sequence)



Students pointed at sequence boundaries, flooding surfaces, stratal terminations, system tracts in computer simulations



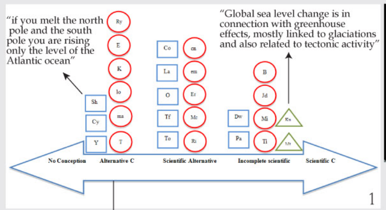
Students completed visual rotation tests (assessing spatial ability)

This iterative analysis allowed to clasify students ideas into different conception categories

RESULTS: CONCEPTIONS & MISUNDERSTANDINGS

Eustasy?

How is it determined & What drives global sea-level changes?



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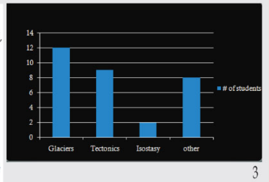

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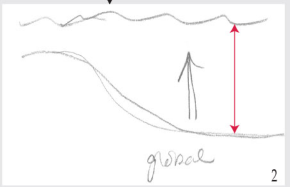

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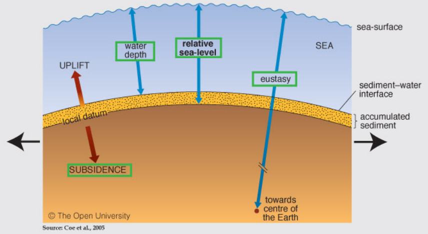
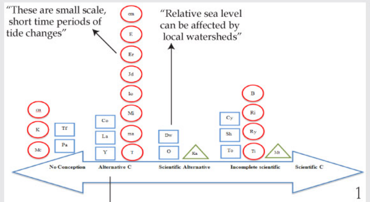
1. Students' responses placed in the continuum from no conception to scientific conception. None of the 27 participants (100 %) mentioned a datum as a point of reference to measure global sea-level change.
2. Student Sh’s arrow indicated the datum as the sea floor. Our case is that 90% of students understand global change sole as a volumetric change in water (no volumetric change in the basin).
3. Principal students’ responses about the main mechanisms driving global sea-level change (e.g. melting of ice sheets, uplifting) other refers to sea thermal exapansion; only four students mention 2 or more factors involved in Eustasy (e.g. tectonics + glaciations).



Source: Coe et al., 2005

We wanted to assess how familar students were with the concept of eustasy. Also, to make sure they would distinguish eustasy from relative sea level and total water depth.

Relative sea-level?



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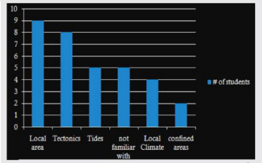

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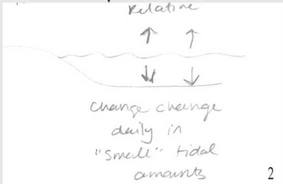

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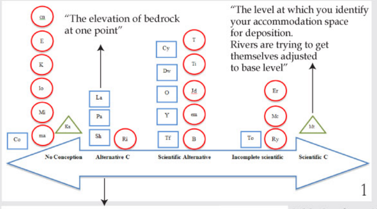
1. Students’ responses to questions related to relative sea level. Notice that about 25% of students are not familiar with the concept.
2. Alternative conception of student *Er*: This assumption is not illogical but incorrect in the context of sequence stratigraphy. In this context relative sea level refers to larger temporal and spatial scales (Thousands to millions of years).
3. Common factors that students associated with relative sea level change. Local area: any change in a local region (e.g. change in local watersheds runoff). confined areas: changes in isolated seas (e.g. black sea caspian sea) 30% of students mention 2 or more factors involved in relative changes (e.g. uplifiting+climate).

Base level?



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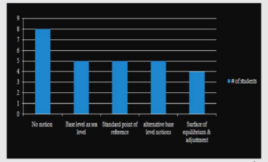

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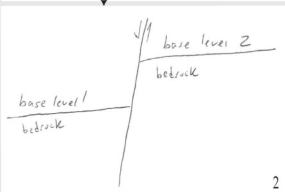
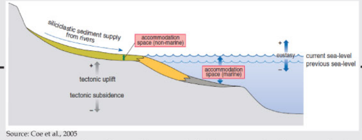


2

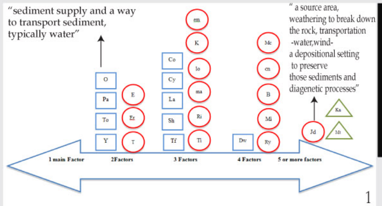
1. Notice that ~40% of senior students (red circles) seem not to be familiar with this principle (even though most of students have taken a geomorphology course).
2. It is arguable that base level may change by tectonic activity (this drawing distantly may represent that case).But, what is missing here is the relationship with changes of the shoreline trajectory and the space available for deposition.
3. Graph summarizing base level notions.



Source: Coe et al., 2005

Through a series of questions and tasks we probed conceptual understanding of base level and related notions such as graded fluvial profile. Also, students had to identify what major factors control sediment accumulation in a basin. This was a surrogate question for probing the concept of accommodation.
(we removed as much terminology as possible from the questionnaires).

Accommodation?



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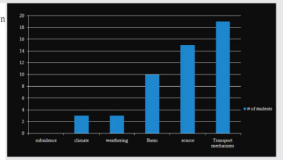

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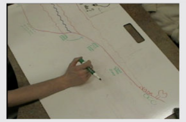

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1. Students’ responses to the concept of accommodation. ranking is based on the numbers of factors that control it. The more factors reported do not imply a more complete understanding of the concept of accommodation.
2. Student drawing a depositional sequence at different time sea-level oscilations, relating sediment distribution, accommodation and lithologies
3. Graph illustrating students’ reported factors controlling sediment deposition in a basin. Notice that subsidence has 0 entries.

CONCLUSIONS

* 70% of students hold incomplete or alternative ideas about concepts of eustasy and relative sea-level.
* 70% do not recognize the temporal scales at which sedimentary processes operate.
* 85% have no notion or hold alternative notions about base level.
* 95% do not associate subsidence as another driving mechanism controlling sediment accumulation in basins.
* 60% poorly integrate tectonic, climate and time magnitudes in their sequence stratigraphic models.
* 85% of students are not familiar with the different marginal marine profile environments and their associated sedimentary structures and lithofacies.

DISCUSSION

* Misunderstandings are common to Graduates, Seniors and Juniors. Student level is not a predictor of mastery of these concepts or terms.
* Complex terminology prevents students’ proper scaffolding of content learning.
* Instructor expertise (carbonates, siliclastic) may bias student conceptions.
* Our data suggest that misunderstandings result more from instructional gaps and teaching bias than to an ability to properly understand concepts.
* Alternative conceptions, however, arise from a cognitive dificulty to think cyclically and dynamically. We documented a tendency toward linear thinking, and an emphasis on declarative knowledge as opposed to procedural knowledge.

IMPLICATIONS

* Diagnosing the most frequent misunderstandings and conceptions allow course trainers to focus instruction on critical concepts (e.g. base level, unconformities) to optimize trainees’ knowledge depth and improve professional training programs.
* Along with field-based experiences, course instructors may be aided by 4D computer simulations which allow manipulation of virtual time variables that are not possible via outcrop exercises (static view) to enhance understanding of temporal and spatial magnitudes of different sedimentary processes.
* This research can shape formal assessment of entry-level trainees to maximize effectiveness and breadth of courses.

ONGOING RESEARCH

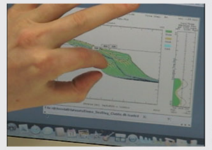
* Expand analysis of students conceptions during computer-aided instruction.
* Understand the correlation between innate spatial ability and task performance.
* Analyze student mental models to elicit deeper information about how students frame their conceptions and build their narratives.

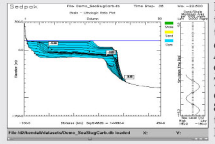
Student *Co* on question about transgressions & regressions. Left hand represents shore line right hand: sea-level.

Documenting representational gestures in both trainers and trainees coupled with verbal reports and drawings provides clues to map mental imagery: Student *Tf*: represents angular unconformity (left hand) overlaid by strata (right hand).

SECONDARY RESULTS

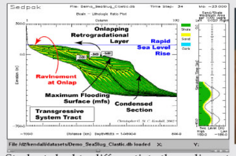
Probing student understanding of concepts in siliciclatic & carbonate margins

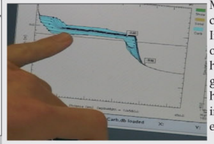




Data analyses suggested that: 75% of students do recognize stratal terminations on diagrams (e.g. downlaps, onlaps, etc.)
40% identify mfs, and SB on diagrams.
90% have no notion of condensed sections
70% are unfamiliar with time magnitudes of tectonic -eustatic & orbital cycles.
80% of students poorly understand the system tracts concept, particularly HST.

Student’s tasks consisted in indetifying stratigraphic surfaces,parasequences, stratal terminations, & system tracts on 2D computer simulations. They also had to estimate time scales of processes.

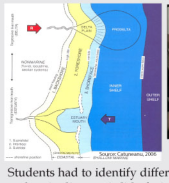


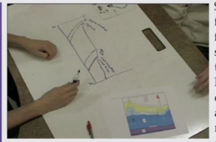


Most students are not familiar with carbonate sequence stratigraphy. Instruction is usually focused on siliciclastic margins. Students had trouble differentiating geometry of system tracts. Students, however do receive substantial instruction on modern carbonate environments.

Students had to differentiate the sediment supply response to sea-level fluctuations between siliciclastic & carbonate margins

Inquirying about environments and lithofacies in the shallow-marine profile





Several students did not fully recognize typical facies associations or sedimentary structures in the coastal profile. Familarity with these set of concepts can be used as a proxy to track sea-level raise & fall oscilations in outcrops, cores, and well logs.

Students had to identify different settings of the continental shelf and main diagnostic lithofacies of each sub-environment.

RELEVANT REFERENCES

* Catuneanu, O., 2006, Principles of sequence stratigraphy. Amsterdam: Elsevier.
* Coe, A.L., Boescence, D. W., Church. K.D., Flint, S.S., Howell, J.A., Wilson, R.C., 2005, The sedimentary record of the sea-level change. The Open University, Cambridge: Cambridge University Press.
* Corbin, J. and Strauss, A., 2008, Basics of qualitative research:Techniques and Procedures for developing grounded theory. Thousand Oaks: Sage.
* Holbrook, J., Scott, R.G., and Oboh-Ikuenobe F., ,2006, Base-level buffer and buttresses: A model for upstream versus downstream control on fluvial geometry and architecture within sequences, Journal of Sedimentary Research, 76, (1): 162-174.
* Kendall, Ch G. St. C., Whittle, G.L. Ehrlich, R., Moore, P., Cannon, R. and, Hellmann, D. R., 1993, Computer sedimentary simulation models sequence stratigraphy. Oil & Gas Journal, v. 91, p. 46-51.
* Kendall, Ch. G. St. C, Moore, P., Whittle, G., and Cannon, R., 1992, A challenge: is it possible to determine eustasy and does it matter? In: Dott, R.H., Jr., ed., Eustasy: the historical ups and downs of a major geological concept. Geological society of America Memoir 180, 93-107.
* Posamentier H.W., and Weimer P., 1993, Siliciclastic sequence stratigraphy and petroleum geology recent development and applications in siliciclastic sequence stratigraphy, Memoirs 58.
* Sumner, D.Y., 2003, Intuitive sequence stratigraphy; replacing lectures with inquiry-based computer labs. Abstracts with Programs - Geological Society of America, v. 35 p. 363-364.
* Wandersee, J.H., Mintzes, J.J, and Novak, J.D., 1994, Research on alternative conceptions in science. In D.L. Gabel (Ed.), Handbook of research on science teaching and learning: A project of the National Science Teachers Associations, 177-210. New York: Macmillan Publishing Company.

ACKNOWLEDGEMENTS

We express our gratitude for their support and feedback to: Jim Ogg, Chris Kendall, Duncan Sibley, Brian Hampton, Lisa Pratt, Brenda Capobianco, and all of our student participants.