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PERSPECTIVE

The future of field-based stratigraphic and sedimentologic studies from a personal perspective

Emiliano Mutti*

Dipartimento di Scienze della Terra, Università degli Studi di Parma,
Viale G.P. Usberti, 157/A - Campus Universitario - 43100 Parma, Italy

It is now quite clear that the advent of 3D-seismic studies, and progress in marine geology techniques, laboratory experiments and numerical models are casting serious doubts among sedimentary geologists on the future of field-based observation and interpretation. One wonders whether field geology is still a valuable tool or whether it should be abandoned in favour of more integrated and sophisticated approaches.

Having spent much of my geological career in field mapping and stratigraphic and sedimentological analyses of exposed sedimentary basin fills of orogenic belts, I must admit that I am still in love with the subtle and elusive challenge of interpreting outcrops and framing them within their stratigraphic context, both vertically and laterally. On the other hand, I've had the opportunity, especially over the last two decades, of gettinginvolved in the study of continental margins and have thus become familiar with modern technology and especially with 3D-seismic. I have enormously benefited from this experience, particularly from integrating 3D-seismic data with core analysis, and certainly my way of examining outcrops has changed accordingly.

I can understand and partly share the enthusiasm of some geoscientists for seismic-based models and highly detailed reconstructions of spectacular seascapes in deep-water. I am also happy to admit that the world discovered through these techniques will profoundly change our perception of sedimentary basins. However, most of these new insights are from divergent continental margins with their unique geodynamic setting and type of tectonic mobility (salt and mud diapirism, listric normal faults and their frontal compressional zones, volcanic activity) and particularly from deep-water sandy successions because of their economic importance (*e.g.*, West Africa, Gulf of Mexico, Brazilian offshore).

A great deal of confusion seems to arise from the attempt to generalize deep-sea depositional settings of these basins, with their channel, channel-levee, and crevasse splay elements, to the exposed deep-water successions of orogenic basins (*e.g.*, Posamentier and Walker, 2006; for a more cautious attempt see Mutti et al., 2009). The two settings are completely different not only because of their geodynamic context but also, in my experience, because of basin geometry, type of facies and facies associations, type of feeder fluvio-deltaic systems, and the absence or presence of bottom currents generated by oceanic circulation. A critical evaluation of the similarities and differences between these types of depositional system seems to be urgent. What can we safely export from orogenic belt basins to divergent continental margin basins and *viceversa*? It would be advisable that before answering this question, seismic interpreters get more acquainted with some of the basic principles of field-based stratigraphy and sedimentology and *viceversa*. In my opinion, bridging this gap will take many years.

Mainly for economic reasons, expensive 3D-volumes are generally restricted to specific portions of continental margin basins in order to identify, explore and exploit hydrocarbon accumulations. The technique is rarely viewed as a tool for understanding regional stratigraphic settings and basin-fill history. Coring is generally scarse and with the obvious limitations inherent in core analysis.

Clearly, 3D-seismic offers an unprecedented opportunity to examine in detail buried sedimentary successions and provides stratigraphers and sedimentologists with a potentially enormous area of future research. However, 3D-seismic will increasingly require a good knowledge of stratigraphic and sedimentologic principles to avoid geologically unreasonable interpretations. Although 3D-seismic interpretation and field-based studies are inherently different in terms of approach and datasets, I believe that outcrop studies, particularly if carried out in well-exposed basin-fills, can be very helpful for seismic interpreters to develop a similar "way of thinking".

In well-exposed basin-fills like, for instance, the Upper Cretaceous and Tertiary of the south-central Pyrenees, Spain, and the Jurassic and Cretaceous strata of the Neuquen basin, Argentina, facies, facies associations and their stratigraphic relationships can be observed in the field in great detail. Where good and lateral extensive outcrops are available, *careful and patient* field work makes it possible to trace these facies and their associations into their lateral equivalents both landward and basinward.

At this point, the geologist faces up a challenge and tries to interpret the facies and facies associations observed and described in the field in terms of inferred processes and depositional environments; by framing these sediments within their stratigraphic context he will probably go farther, attempting to understand transgressions, regressions and

*Corresponding author: *emiliano.mutti@unipr.it*

unconformity surfaces, i.e. entering the fascinating world of sequence stratigraphy and its implications. A very strong feeling for rocks (and their beauty) and a good knowledge of the literature (including old text books) are clearly essential prerequisites. Becoming familiar with rocks will pay off later, when examining cores.

It is my conviction that an approach of this kind can only be attempted in outcrop studies and that there is still ample room for improving our understanding of sedimentary successions. Of course, this should be done without preconceived ideas, i.e. recognizing that even the "universal" facies of Walker (2006, p. 6) can be revisited and re-interpreted. As an example, I would suggest that HCS ("storm-dominated shelf deposits" of Walker, 2006) could also be interpreted as a common type of sandy facies in delta-front deposits generated by hyperpycnal flows, and that "thin-bedded turbidites with climbing ripples, convolute lamination and ripped-up mud clasts" ("levee deposits" of Walker, 2006) as a common prodeltaic deposit of more dilute hyperpycnal flows in the same kind of delta system (*e.g.*, Mutti et al., 2003). In his highly provocative attempt at "demystifying myths", Shanmugam (2000, 2003) has suggested that even classic deep-water facies types generally inferred to be the deposits of sediment gravity flows should be reconsidered as to their mode of emplacement and geologic significance.

In summary, modern facies analysis should maintain its roots in outcrop studies. What one can learn from practising this kind of study can be then easily used as a guide for more integrated approaches in which direct observation of rocks is not possible or limited to cores. As pointed out by Schlager (2000) in a thoughtful article on the future of sedimentary geology, seismic images remain non-unique in their interpretation. Seismic interpetations require continuous input from geologic principles or from ground truth and knowledge of regional geology to constrain the number of possible interpretations. At this point it is certainly appropriate to mention here that seismic stratigraphy and its derivatives could only have originated and developed over the last three decades only through the application of a simple geologic principle stating that seismic reflectors are an expression of stratification in the subsurface and can thus be viewed as stratal units with a chronostratigraphic significance. The concept of the chronostratigraphic significance of stratal units stems from the basic paper of Campbell (1967) on stratification, i.e. from field observations.

Based on my experience, I would thus strongly urge young geoscientists to acquire a sound background in field work before moving to the fascinating but still partly virtual world of seismic interpretation. It is easy to anticipate that within few years such a "sound background" will be required by oil companies when hiring new people. I still remember what I was told by my manager at the time I was working for a major oil company more than 40 years ago and was a young geologist fascinated by new concepts. He said: "Emiliano, never forget that we drill rocks, not concepts". I have always cherished his advice.

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