reservoir) and displayed as an attribute map showing the lateral distribution of the computed attribute in a 2D map view. A large number of attributes exists, like Integrated Seismic Amplitude (integrates the amplitude of a seismic trace over a volume), Integrated Reflection Strength (integrates the reflection strength of a seismic trace), Reflection Heterogeneity (measures the trace length) or Integrated Instantaneous Frequency (integrates the instantaneous frequency of a trace) and many others. These different attributes can help the interpreter as they can highlight various features of the data that would not be visible otherwise.
It is known that the attribute response of one single attribute is guided simultaneously by fluids, facies, pressure etc. Furthermore, different attributes show different sensitivities to fluid, facies, etc. Thus, the key question in attribute analysis is to find out which attributes show the desired feature. Hence, to find out the fluid or facies distribution within a reservoir it is necessary to combine several attributes and to filter out the desired information. The method of using seismic data and to "read" from them fluid or facies information is an inversion process. SeisClass is such an inversion tool supplying additional model constraints to assist exploration geophysicists, reservoir engineers and project management in generating realistic earth models. The use of SeisClass maximises the use of information derived directly from seismic reflection data. The basic function of SeisClass is to discriminate statistically or non-statistically between "classes" (e.g. oil-water, sand-shale), these classes being based upon seismic attributes or other input data. SeisClass produces class maps, each different class being related to a distinct reservoir property. The inversion of the seismic response of a reservoir into classes showing the distribution of certain reservoir properties is called Reservoir Classification.
Two main classification modes exist in SeisClass: Unsupervised Classification (based on natural clustering techniques) and Supervised Classification (based on learning strategies or training data input). For supervised classification the clustering algorithm has to be supplemented by a learning strategy based on training data. The training data can, for instance, be picked around well-locations or based on prior geological knowledge. A training data element is a vector that contains attribute values coming from the same location (cell or bin) for all attribute grids used in the classification. Different statistical and neural network algorithms have been implemented in the classification module.
Two case studies will be presented to demonstrate the successful application of attribute analysis and classification during different phases of oilfield development.
Case study one is a carbonate field during the early exploration phase with seismic data being the only information source available. The issue was to map the distribution of carbonate mounds which are the main reservoir. Volume attributes were computed on a chaos cube and a variance cube. The chaos cube and the variance cube are different approaches to measure the lateral continuity of a seismic signal. They were applied because carbonate mounds show a different seismic texture than lagoonal sediments. K-Means Classification (an unsupervised classification method), which is based on the natural clustering of attribute data, was successful in quickly (several hours) mapping the distribution of carbonate mounds. Manual mapping (Inline by Inline) of the mounds would have taken several weeks. This way of reservoir mapping is very quick and, additionally, helps to construct paleogeographic models and play concepts very early during the exploration phase.
The challenge of the second case study was to map the distribution of channel sands encased in a shale/coal sequence of a fluvial depositional environment. The mapping of sand channels was important for field development and well planning. Production wells had to be placed at locations where an optimum vertical connectivity of sand channels occurred. Input data were shear wave data (converted waves) aquired as 4C data (ocean bottom cable method), so volume attributes were computed on a S-wave data set. In this case study a lot of well information was available. Lithologic information based on wells was used to train the inversion tool. Hence, a neural network classification method (supervised classification) was applied to invert for the classes sand vs. shale/coal. Afterwards drilled horizontal wells confirmed the prediction of the distribution of sand.

Carbonate depositional systems – from factories to sequences

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Limestones and dolomites make up less than 25 % of the sediment mass of the Earth but they merit special attention: they contain nearly 50 % of the known reserves of oil and gas, host some of the largest aquifers in the world and play a significant role in the carbon cycle of the our planet. This presentation revolves around the production of carbonate material and the ordering of carbonate sediments into depositional sequences. Recent progress in both areas has been very significant and undoubtedly will improve the subsurface prediction of carbonate rocks – a central task in petroleum geology and hydrogeology.
Carbonate precipitation in the ocean proceeds in three basic modes – abiotic, biotically induced, i.e. triggered by organisms, and biotically controlled, i.e. fully determined by organisms (LOWENSTAM & WEINER 1989). The three modes combine in a variety of ways to produce carbonate sediment. When viewed on the scale of formations and global facies belts, three carbonate production systems, or "**factories**", emerge (REITNER & NEUWEILER 1995, JAMES 1997, SCHLAGER in press): (1) the tropical shallow-water factory, dominated by biotically controlled (mainly autotrophic) and abiotic precipitates; (2) the cool-water factory, dominated by biotically controlled (mainly heterotrophic) precipitates; and (3) the mud-mound factory, dominated by abiotic and biotically induced (mainly microbial) precipitates.
Sedimentation rates and growth potential of all three factories decrease as the time span of observation increases. This scaling trend has real physical meaning and is related to the episodic nature of sedimentation and the pervasive distribution of hiatuses in the record. The growth potential can be estimated from the maximum observed rates of aggradation (SCHLAGER 1999). The tropical system shows the highest rates - 10^4 m/yr at 10^3 yr, decreasing to 10^2 m/yr at 10^7 yr. The maximum rates of the cool-water system amount to only 25 % of the tropical standard in the domain of 10^6-10^8 yr. Only the short-term rates of cool-water carbonates occasionally equal those of the tropical factory because of extensive reworking and local trapping of sediment. The growth rates of the mud-mound system significantly exceed cool-water rates and rival those of the tropical factory. However, the mud-mound system exports less sediment than its tropical counterpart and is, therefore, somewhat less productive.
Sediment accumulations of the three factories differ in composition, geometry and facies patterns and some of these differences appear prominently in seismic data. The characteristic accumulation of the tropical factory is the flat-topped platform with a rim of reefs or sand shoals. Cool-water carbonates lack rim-building capability and tend to produce seaward-sloping shelves similar to siliciclastic systems. The typical accumulation of the mud-mound factory are convex-up mounds that normally form on gentle slopes in tens to hundreds of meters of water depth.
Carbonate sequence stratigraphy. The standard model of sequence stratigraphy is based on siliciclastic systems. Carbonates share many of the basic trends but also deviate from the standard model in several respects. These differences are most apparent on tropical carbonates.
Accumulation geometries and of tropical carbonates that build close to sea level, are governed by two rates: if we call A the

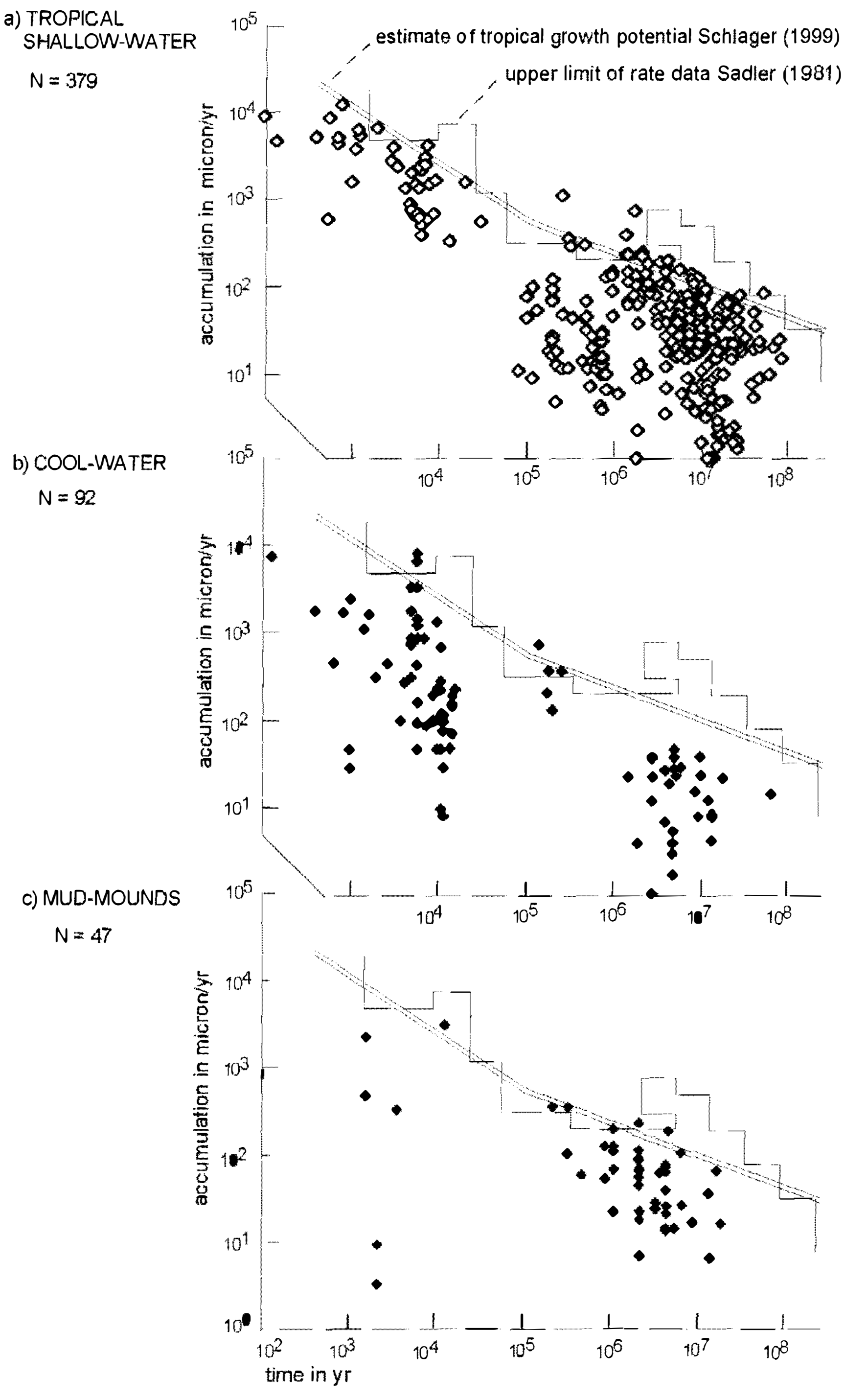

Fig. 1: Sedimentation rates of tropical, cool-water and mud-mound carboantes plotted against length of observation time. The decrease of rates with increasing time has physical meaning and is not simply caused by the fact that one variable, time, appears on both axes. See text for discussion. After SCHLAGER (in press), modified.

accommodation and G the volume of sediment produced by carbonate-secreting organisms, then geometry and facies of the platform deposits are fundamentally controlled by the balance of dA/dt, the rate of accommodation creation, and dG/dt, the rate of carbonate growth. Fig. 2 shows the effect of these rates on geometry. A similar diagram could be drawn up for facies patterns. Fig. 2 distinguishes between the growth rate of the rim and the interior of the platform because the rim typically produces more sediment than the platform interior. Fig.1 shows that the differentiation into transgressive and highstand systems tracts may be caused either by changes in the rate of accommodation creation (i.e. sea level fluctuations) or by changes in carbonate growth; only the formation of a lowstand tract is a sure indication of sea-level change.

The lower two panels of Fig. 2 show two geometries that occur only in carbonate rocks. Both are related to the growth potential of the carbonate factory. "Drowning" of reefs and platforms occurs when the rate of sea-level rise exceeds the growth rate of both rim and platform interior such that the entire platform subsides below the photic zone and shoalwater carbonate production ceases. The result is a pronounced transgressive systems tract that is not, or only after a long period, covered by another highstand tract. The transgressive tract is often replaced by a transgressive surface that may appear as a pronounced unconformity, the "drowning unconformity" in outcrop or seismic profile. Another geometry diagnostic of carbonate platforms is the "empty bucket" where the rim keeps pace with the rising sea but the lagoon falls behind. The empty bucket stage may be the beginning of platform drowning. Alternatively, it may be the early part of a highstand tract where the platform recovers and the rim progrades both into the empty

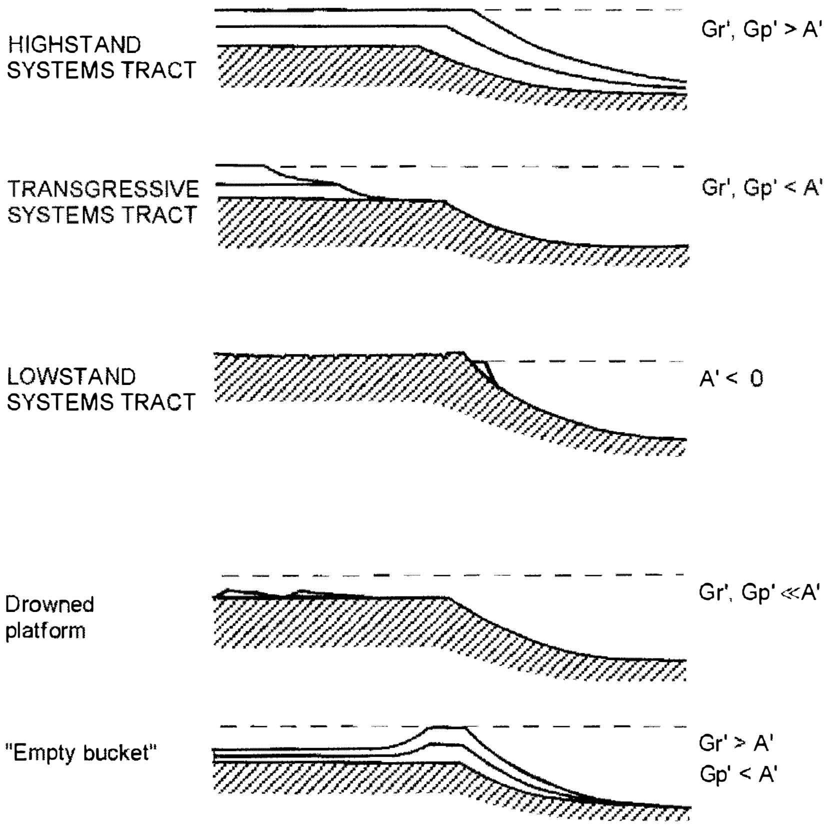

Fig.2: Carbonate systems tracts related to the balance of two rates - dA/dt (= A´), the rate of change of accomodation creation, and dG/dT (= G´), the rate of carbonate growth. The top three panels represent the systems tracts of the standard model of sequence stratigraphy, the lower two panels are specific for rimmed carbonate platforms. Complete drowning occurs when the groth potential of the factory is below the rate of relatve sea-level rise; the empty bucket forms when the rim can keep up with the rise, but the lagoon cannot. After SCHLAGER (1999).

lagoon and towards the basin. This bidirectional progradation is again characteristic of carbonate systems.
Cool-water carbonates follow the standard model more closely than tropical accumulations. They lack rims, have gentle slopes and rework much of their material during lowstands, just like siliciclastics. Mud-mound systems are difficult to fist in the standard model because they normally operate in greater water depth and tend to remain flooded even during lowstands of sea level. Consequently, exposure unconformities that could serve as sequence boundaries are not as distinct as in tropical or cool-water deposits.
The margins and slopes of rimmed carbonate platforms are sedimentologically complex and difficult to image seismically. One imaging problem are the tight curvatures and steep slope angles at the platform margin. Furthermore, platform flanks are prone to developing pseudo-unconformities in seismics – bedding patterns that appear as unconformities in seismic data but are caused by lateral facies changes. Pseudo-unconformities tend to form at the periphery of reefs and carbonate platforms because the carbonate systems produce their own sediment that often interfingers with terrigenous muds on the flank of the build-up. The result are rapid facies changes combined with rapid thickness changes of beds. Near the limit of resolution, the seismic tool may show lap-out patterns (such as onlap or downlap) at facies changes rather than bedding surfaces.

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Stratigraphische Modellierung von miozänen syntektonischen Sedimenten an einer listrischen Abschiebung im Eisenstädter Becken (Burgenland, Österreich)

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Miozäne E-W extensionelle synsedimentäre Tektonik führte zur Anlage einer N-S streichenden, mit 60° nach W einfallenden listrischen Abschiebung, die den Rand des Eisenstädter Beckens zum Ruster Hügelland bildet.
Diese Störung und die daran angelagerten syntektonischen klastischen Sedimente des Sarmatiums (Mactren Schichten) und Pannoniums (Zonen B, C, D und E) sind in der Kiesgrube "Kaufer" südlich von St. Margarethen (Burgenland) in einer *Rollover-Antiklinale* aufgeschlossen. Es kamen schräggeschichtete mittel- bis grobkörnige sandige Kiese, feinkörnige siltige Sande und Silte mit einer Gesamtmächtigkeit von etwa 30 m zur Ablagerung. Die wechsellagernden Straten sind auf einer Strecke von 200 m normal zur Störung aufgeschlossen und zeigen kontinuierlich steigende Schichtmächtigkeiten von W nach E (*growth strata*).
Die Analyse von Störungsmustern in der *Rollover* Struktur entlang einer Kiesgrubenwand zeigt, daß die horizontale finite Ex-