Seismic Stratigraphy

Seismology is the study of earthquakes and the structure of Earth on the basisof the characteristics of seismic waves. Although the broad subject of seismologylies outside the scope of this book, some aspects of seismology havea very important application to stratigraphy. The emphasis of this chapter is onwhat is commonly referred to as exploration seismology and, more specifically, onapplication of the techniques of exploration seismology to stratigraphic study. Explorationseismology deals with the use of artificially generated seismic waves toobtain information about the geologic structure, stratigraphic characteristics, anddistributions of rock types. The techniques of exploration seismology were developedinitially to locate structural traps for petroleum deposits, and they are stillused extensively for that purpose; however, seismic methods can also be appliedto stratigraphic problems.

Seismic stratigraphy is the study of seismic data for the purpose ofextracting stratigraphic information. Seismic stratigraphy is a relatively new science,born in the 1960s. Because of its wide applicability to subsurface studyboth on land and at sea, where other types of stratigraphic data are few, it has alreadyachieved an important position alongside the more traditional branches ofstratigraphy.

The use of seismic methods for obtaining information about subsurface rocks andstructures involves the natural or artificial propagation of seismic (elastic) waves.These waves pass downward into Earth until they encounter a discontinuity andare reflected back to the surface, where they can be picked up by detectors. Seismicwaves travel at velocities ranging from less than 2 km/s (some sediments) tomore than 8 km/s (some ultramafic rocks), depending upon the kinds of rocksthrough which they pass and their depth below Earth's surface. If we know thevelocity with which seismic waves travel through a particular kind of rock and ifwe can time their passage downward to a reflector and back to the surface, then
we can calculate the depth to the reflecting horizon. This principle forms the basisfor application of seismic methods to geologic study.

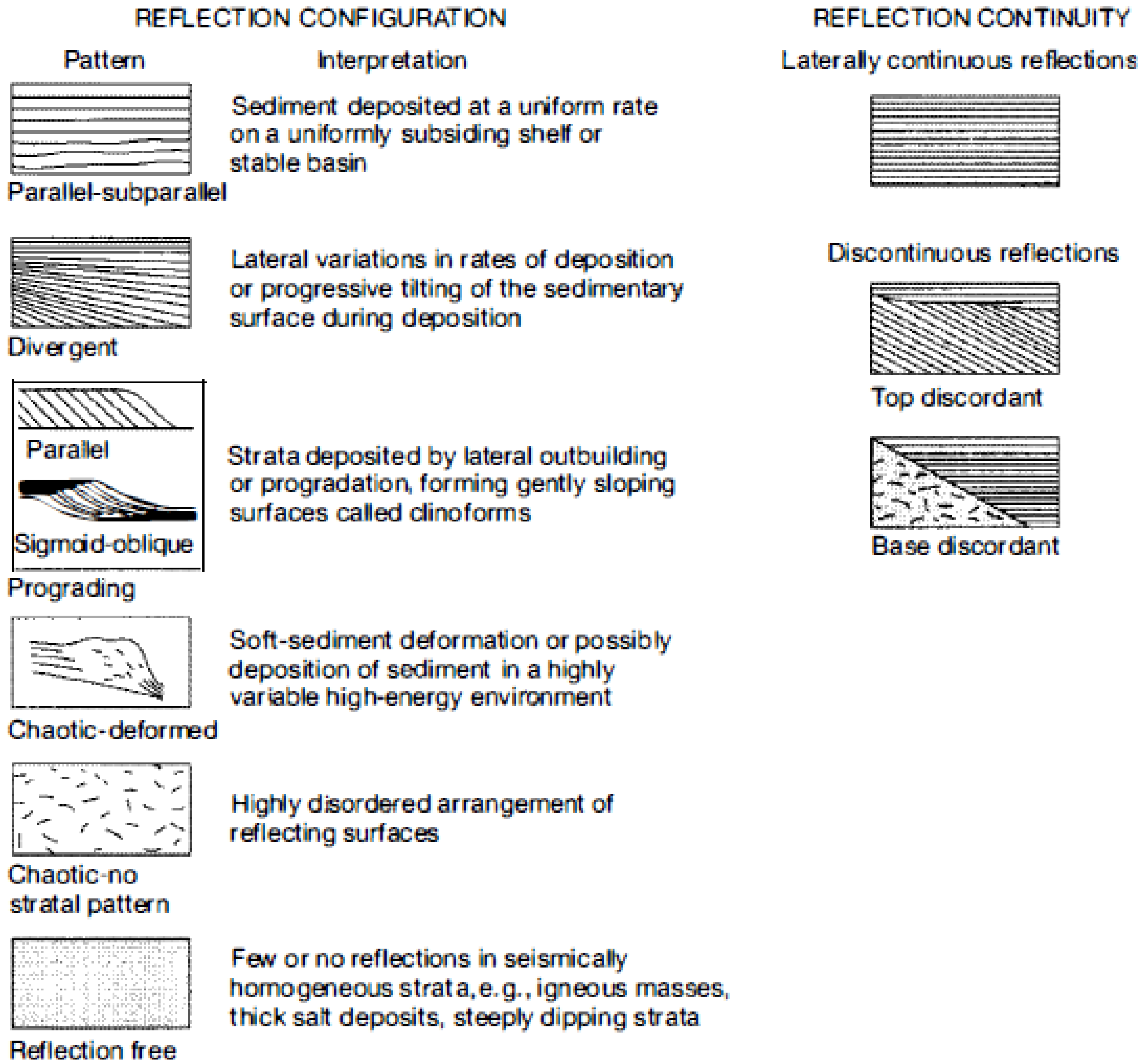
Parameters Used in Seismic Stratigraphic Interpretation

Reflection Configuration. Reflection configuration refers to the gross stratificationpatterns identified on seismic records. As illustrated in Figure below, parallel,divergent, and prograding patterns can be interpreted in terms of primarydepositional conditions or characteristics (the upper part of Fig. further illustratesparallel reflectors). Chaotic patterns are the result of soft-sediment deformationor other kinds of deformation that produce a disordered arrangement ofreflecting surfaces. So-called reflection-free patterns display no identifiablestratal reflections; reflections appear simply as random "noise."

Reflection Continuity

Reflection continuity depends upon the continuity of thedensity-velocity contrast along bedding surfaces or unconformities. It is closelyassociated with continuity of strata, and it provides information about depositional process and environment.

Theamplitude of seismic waves displayed on seismograms is, among other things,an indication of bed thickness and spacing. (As mentioned, amplitude is equal toone-half the height of the wave above the adjacent trough.) If bed thickness is lessthan the wavelength of the seismic wave-for example, one-fourth of a wavelength-the reflections from the top and base of the bed can be phased together togive exceptionally large amplitudes.



Reflection frequency refers to the number of vibrations or oscillations ofseismic waves per second. It is numerically equal to wave velocity divided bywave length. The frequency of a seismic wave is commonly expressed in hertz (Hz)or kilohertz (kHz). A hertz is a unit of frequency equal to one cycle per second; akilohertz is 1 000 hertz. The frequency of seismic waves affects both the depth ofpenetration of the waves into the subsurface and the resolution of the seismicrecords, that is1 the sharpness with which details of the seismograms can be distinguished.
Lower frequencies give greater depth of penetration but less resolvingpower. The frequency of seismic waves is induced by the particular energy soundsource used to create the waves. As the waves pass downward through subsurfaceformations and are reflected back to the surface, the initial induced frequency isattenuated by bed thickness, Frequency is also

affected by lateral changes in fluid content ofbeds (the presence of hydrocarbon accumulations, for example) and by lateralthickness changes in beds.

Interval velocity refers to the average velocity of seismic waves between reflectors.Seismic wave velocity is affected by several factors, especially porosity,density, external pressure, and pore (fluid) pressure.Porosity has a particularlysignificant effect on velocity, which increases as porosity decreases. Thus, becauseporosity commonly decreases with depth, velocity increases with depth. Velocityalso increases with density of the rocks and with increasing overburden pressure.Velocity decreases with increasinginterstitial fluid pressure; the presence of gas at low saturations in thepore spaces of the rocks also causes a decrease in velocity.

The external form or geometry of stratigraphic bodies that generate seismicreflections can be interpreted from seismic data. Thus, these datacan be used to identify "seismic facies/' which may be interpreted in terms of depositionalenvironments of the lithologicanalogs of these seismic facies.

Seismic facies parameters	Geologic interpretation
Reflection configuration	Bedding patterns
	Depositional processes
	Erosion and paleotopography
	Fluid contacts
Reflection continuity	Bedding continuity
	Depositional processes
Reflection amplitude	Velocity-density contrast
	Bed spacing
	Fluid content
Reflection frequency	Bed thickness
	Fluid content
Interval velocity	Estimation of lithology
	Estimation of porosity
	Fluid content
External form and areal association of seismic facies units	Gross depositional environment
	Sediment source
	Geologic setting