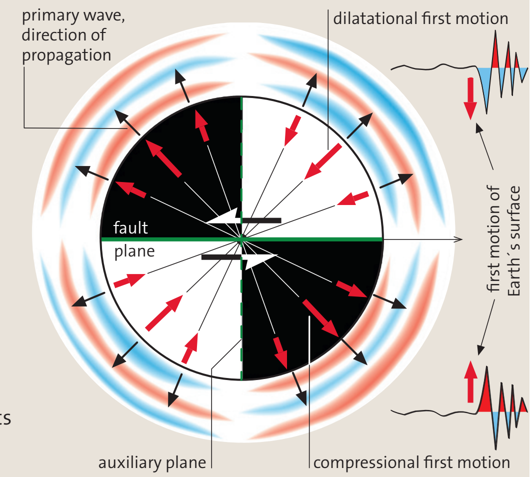
Fault-plane-solutions of earthquakes

The orientation of planes of movement at plate boundaries can be deduced from earthquake data. In the case of an earthquake triggered at a fault plane, the two blocks move by creating an instantaneous offset up to several meters. This results in the generation of the two types of seismic body waves. Primary (P-) waves oscillate in the longitudinal direction of propagation. They are faster than secondary (S-) waves that oscillate transversally. If all of the seismic data from a given earthquake collected around the Earth are put into a diagram, the quadrants and the two separating planes can be determined with their spatial orientation (**Fig. 2.14**). In the two quadrants that are in the direction of movement of each block, the first motion of the primary waves is away from the earthquake focus and an observer on the Earth's surface first receives a push; the wave starts with a compressive movement (compressive first motion shown as black quadrants in **Fig. 2.14**). First motion in the other two quadrants, shown in white, is in the opposite direction; it starts with a tension and is dilatational. Each of these motions is registered by the seismograph.

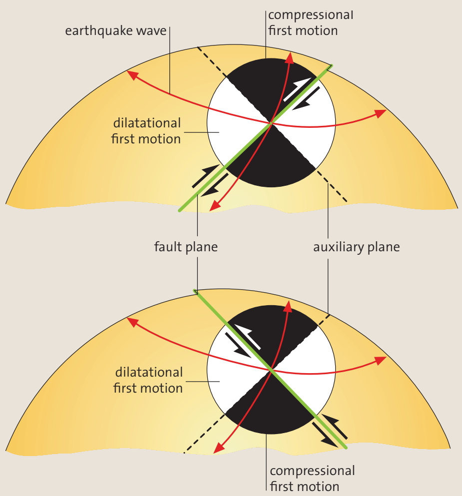
Using the principles discussed above, the quadrants and the two separating planes can be determined with their spatial orientation (**Fig. 2.14**). One of these planes represents the slip plane generated by the earthquake; the other one is an aiding plane that has no use in nature. However, initially it is not possible to decide which one of these two planes was the slip plane. Commonly this can be deduced from geological observations if the approximate orientation of a fracture zone is known. On the other hand, careful analysis of seismic data generated by the aftershock activity following every large earthquake provides the opportunity to identify the slip plane because of the shift of the seismic centers. If the slip plane is known, the sense of movement is easily detected (**Fig. 2.15**). Direction of movement in the slip plane is orthogonal to the aiding plane. A process similar to that used for analyzing P-waves can also be used for the analysis of S-waves that oscillate orthogonal to the direction of propagation.

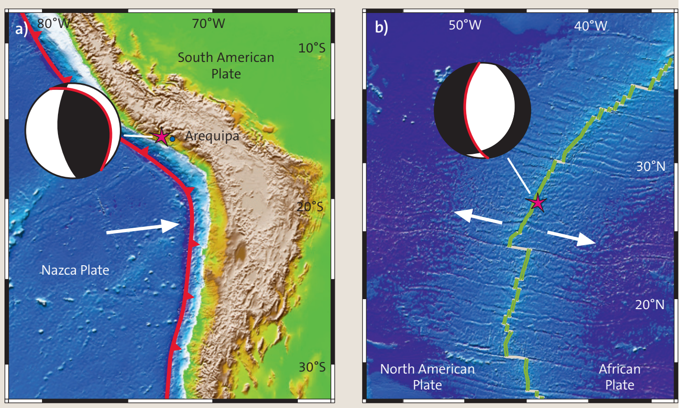
Using this method, which is called fault-plane-solution, the orientation of a slip plane and the sense of movement can be determined with high accuracy. Fault-plane-solutions allow for a reconstruction of plate boundaries and their movement patterns (**Fig. 2.16**). The analysis of earthquake first motion data impressively confirmed the concept of three different types of plate boundaries (Sykes, 1967).



▶ **Fig. 2.14** Principle of fault-plane-solutions of an earthquake hypocenter. The fault plane of the earthquake (orthogonal to the paper plane) and an orthogonal virtual aiding plane define four quadrants. First motions of the primary waves oscillating in the propagation direction and expressed by vertical motions in the soil indicate the sense of movement of the blocks displaced during the earthquake. Seismograms subdivide two quadrants with compressive and two quadrants with dilatative first motion.

▼ **Fig. 2.15** Ambiguity of fault-plane-solutions illustrated by an earthquake that produces an overthrust. Illustration is a schematic vertical section through the Earth.

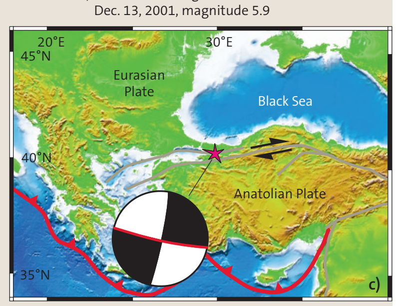




a) Arequipa, Peru. June 23, 2001, magnitude 8.1

b) Mid-Atlantic Ridge, 27.1°N, 44.3°W. Dec. 13, 2001, magnitude 5.9

▶ **Fig. 2.16** Examples of fault-plane-solutions of recent earthquakes at the three different kinds of plate boundaries. Quadrants of the first motions of earthquake waves are shown in stereographic projections of the lower hemisphere. Earthquake (a) at a subduction zone (Peru), (b) at a mid-ocean ridge (Atlantic), and (c) at a transform fault (North Anatolian Fault). Black quadrants – compressive first motion. Red line – active fault plane. Earthquake data are from the internet catalogue of the National Earthquake Information Center (US Geological Survey).



c) Izmit, Turkey. Aug. 17, 1999, magnitude 7.4