EAGE 75TH ANNIVERSARY

1951–2026

ADAPTING TO A WORLD IN TRANSITION

EUROPEAN ASSOCIATION OF GEOSCIENTISTS AND ENGINEERS

Permanent passive monitoring station

MICROSEISMIC MONITORING PERSPECTIVE

Early history

Passive seismic monitoring - listening to the Earth rather than actively probing it with seismic sources - has its roots in early earthquake seismology. In the late 19th and early 20th centuries, scientists developed instruments to detect and record naturally occurring seismic waves, using them to infer the Earth's internal structure. By analysing how waves reflected and refracted through the subsurface, geophysicists established the principles and tools that would later underpin passive seismic applications in industry.

The shift from global earthquake studies to localised microseismic monitoring began in the mid-20th century as instrumentation improved and resource developers sought better ways to understand subsurface geomechanics. Microseismic methods offered a key advantage: they relied on detecting naturally occurring or induced seismicity often too small to be felt but rich in information about stress changes and rock failure.

Early industrial use emerged in mining, where monitoring microseismic activity helped anticipate dangerous rock bursts. This idea - that small seismic events could illuminate larger-scale processes - translated naturally to subsurface energy applications.

A major turning point came in the mid-1960s when earthquakes linked to waste fluid injection at the Rocky Mountain Arsenal near Denver suggested a link between fluid injection and induced seismicity. Soon after, US Geological Survey experiments at Chevron's Rangeley Colorado field demonstrated a direct correlation between fluid injection, pore pressure and microseismic activity - establishing the physical link between fluid flow and seismic response.

This link was exploited in enhanced geothermal systems (EGS) research during the 1970s and 1980s. The hot dry rock experiments such as that at Fenton Hill, New Mexico, demonstrated that fluid injection into low-permeability rock could create a connected fracture network. Microseismic monitoring was used to map this process in real time by locating thousands of tiny, induced events. For the first time, operators could infer the geometry of a stimulated reservoir as it developed, making seismic monitoring an operational tool.

These geothermal experiments established key methodologies still used today. They also confirmed that microseismicity could serve as a reliable proxy for fracture geometry and reservoir complexity.


Microseismic operations in action.

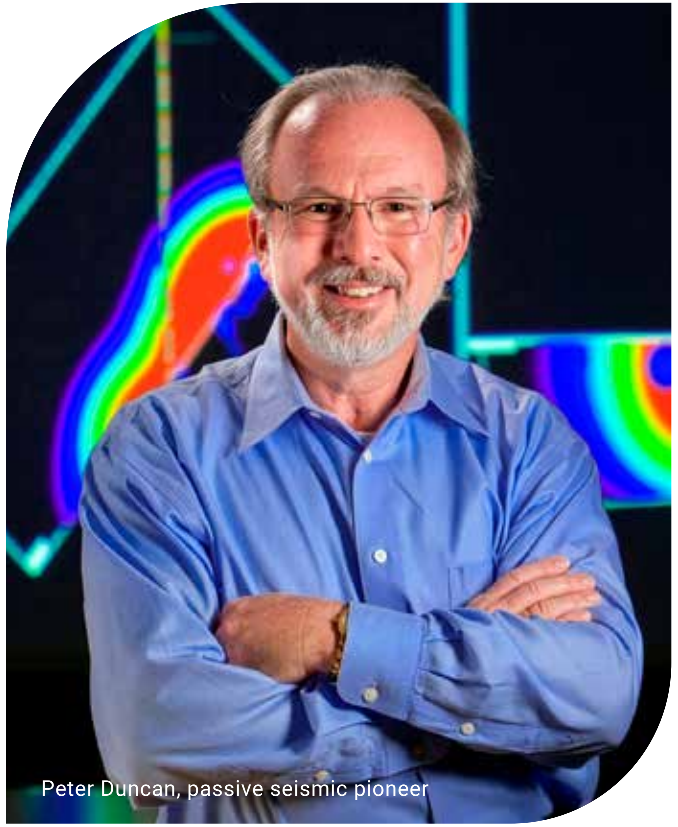
Birth of shale applications

The oil and gas industry began adopting these techniques more broadly in the 1990s, with early hydraulic fracturing trials in formations such as the Cotton Valley of East Texas. In these tests, geophones deployed in nearby wells recorded acoustic emissions generated during fracture growth. By triangulating from seismic arrivals, geophysicists could map fracture height, length and orientation—parameters that had previously been highly uncertain.

As shale development accelerated in the 2000s, microseismic monitoring became a standard diagnostic tool across unconventional plays. Peter Duncan, founder of Houston-based Microseismic in 2003, pioneered applications of passive seismic technology for optimising shale oil and gas operations, particularly mapping fractures and providing early warning of problematic seismicity.

Advances in sensor technology, processing algorithms and real-time interpretation improved both the resolution and reliability of fracture imaging. Surface arrays allowed for a more complete analysis of the seismic events and an expanded areal coverage as horizontal well lengths increased.

Today, microseismic monitoring occupies a central role in unconventional reservoir development. It is used not only to map fracture geometry, but also to assess stage efficiency, monitor fracture driven interaction (FDI) between wells, and evaluate environmental risks such as induced seismicity. At the same time, the field continues to evolve, incorporating


Peter Duncan, passive seismic pioneer

machine learning techniques and integrating with other data streams such as fibre-optic sensing. The practice is finding application to CO_2 sequestration monitoring and is being utilised in modern geothermal field development.

From its origins in earthquake science to its role in hydraulic fracturing, microseismic monitoring has evolved into a critical technology for understanding and managing complex subsurface systems.