



# MICROSEISMIC MONITORING

FOR THE ENERGY SECTOR

UNDERSTAND  
OPTIMISE  
PROTECT





PROJECT MANAGEMENT



TURNKEY SOLUTIONS



FIELD SERVICES, INTEGRATION  
TESTING AND COMMISSIONING



MAINTENANCE AND AFTER-SALES  
TECHNICAL SUPPORT



INSTRUMENT RENTAL POOL

Est.  
**1985**

PIONEER OF  
THE MINIATURE  
FORCE-FEEDBACK  
BROADBAND  
SEISMOMETER

**50,000**

INSTRUMENTS  
SUPPLIED TO  
CUSTOMERS  
ACROSS ALL  
CONTINENTS

**1,000  
+**

OCEAN BOTTOM  
SEISMOMETERS  
DEPLOYED IN  
ALL MAJOR  
OCEAN BASINS

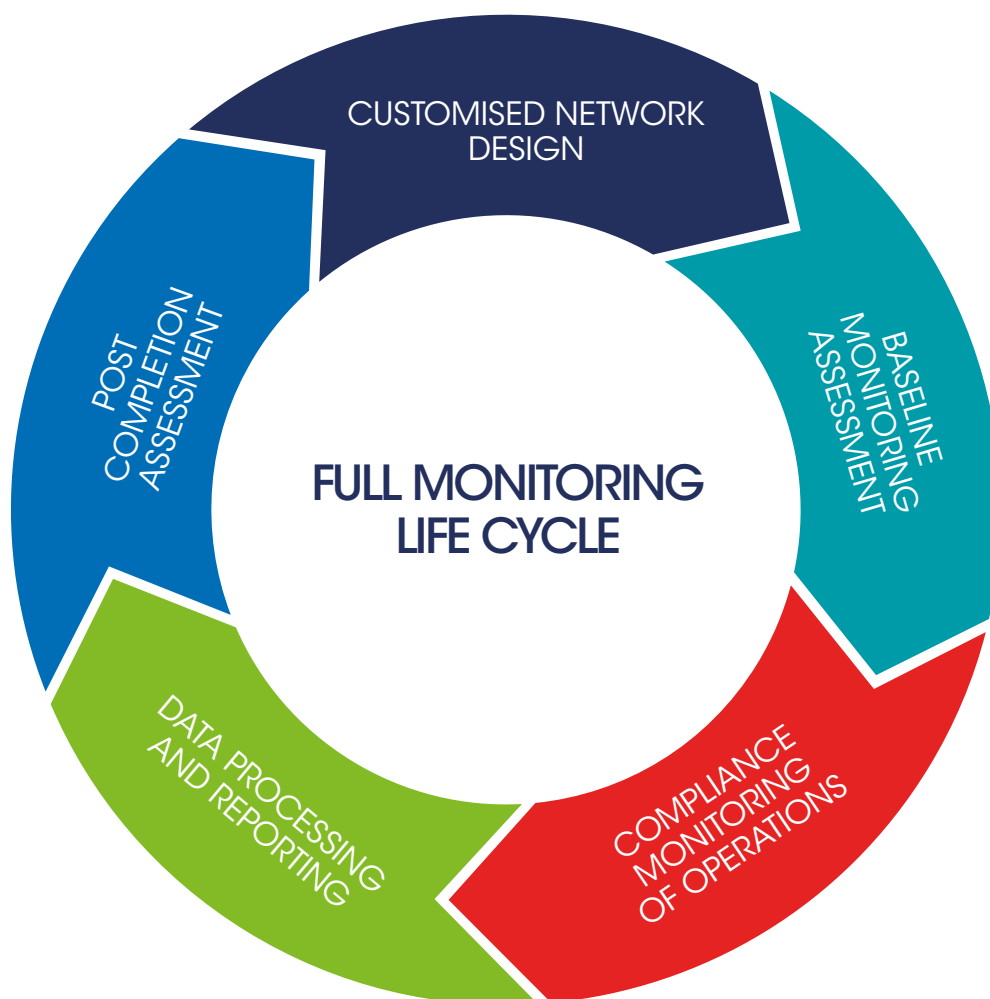
# Next-generation broadband seismic monitoring for a changing energy landscape.

Broadband seismic data plays a vital role in precisely estimating earthquake magnitudes - an essential requirement for meeting regulatory compliance in monitoring induced seismicity. This is especially crucial for subsurface injection activities in energy production and carbon sequestration, where accurate seismic assessments help ensure safety, operational integrity, and public trust.

Our solutions, built on world-renowned broadband instrumentation, provide the reliability and precision you need to operate with confidence and meet the highest industry standards.

In collaboration with our trusted partners, we offer comprehensive project management and full turnkey solutions across the entire monitoring life cycle. From network design and instrumentation supply to installation, maintenance, data processing, threshold alerts, and regulatory reporting - we provide everything needed for seamless seismic monitoring.

With four decades of experience, Güralp-installed arrays have delivered continuous, reliable performance for clients around the world.



# MONITORING SOLUTIONS

Our microseismic monitoring solutions can be adapted to meet your requirements allowing you to utilise as much of our expertise as you need.

## WORLD-CLASS BROADBAND INSTRUMENTATION

Our globally adopted smart sensors are engineered for easy deployment, delivering broadband quality seismic performance and long-term reliability in the field. To streamline setup, we offer a range of plug-and-play field-deployment kits for efficient installation in any environment.

## EXPERTISE IN THE FIELD

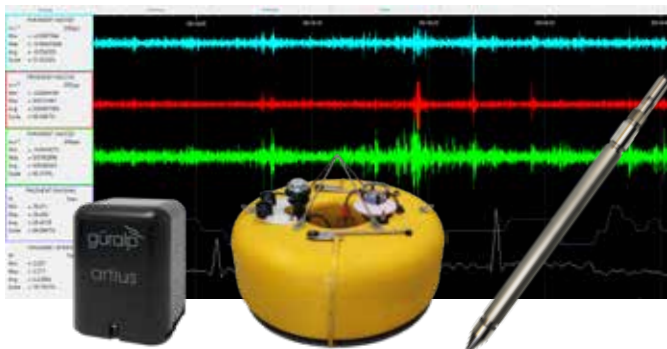
Our experienced field service engineers can deliver on-site installation, servicing, and decommissioning services. Supported by our in-house technical team, they have access to expert assistance whenever specialist support is needed.

## RELIABLE, UNINTERRUPTED OPERATIONS

Multi-instrument voting systems reduce false positives and minimise disruption. When thresholds are triggered, instant guidance supports rapid response. We also offer tailored integration with your emergency protocols, ensuring alerts are aligned with your safety procedures.

## ADVANCED INSTRUMENT AND NETWORK MANAGEMENT

Our seismic instruments integrate seamlessly with Discovery—a powerful, unified platform for managing sensors and monitoring station health in real time. Discovery's intuitive interface and specialist modules support detailed analysis, alerts, and system configuration, putting full control at your fingertips.



## DATA ARCHIVING AND NETWORK MANAGEMENT – CLOUD OR LOCAL OPTIONS

Record, forward, and archive your seismic network data with flexible solutions, either cloud-based or locally hosted.

The Guralp Data Centre (GDC) offers a scalable, cloud-based archiving service for networks ranging from 5 to 200+ instruments. It provides a synchronous data buffer for up to 12 months, adding redundancy without disrupting existing workflows based on SEEDlink.

- A scalable, secure solution for reliable data redundancy
- Store and archive data from over 200 instruments
- Synchronous buffer for up to 12 months
- Adds a parallel, non-disruptive path to existing workflows
- Compatible with third-party processing software
- Easy access via secure web portal
- Search and download data by date and time

## POWERFUL MONITORING TOOLS

- Beyond archiving - manage and maintain your entire network
- Integrated network state-of-health tools
- Mass configuration of instruments
- Real-time and historical latency performance analysis
- Bandwidth usage and outage tracking
- Automated station offline alerts

## CLOUD-BASED CONVENIENCE

- Desktop-as-a-Service (DaaS) technology offers the power and flexibility of desktop applications via any web browser
- User access is controlled individually for security
- Hosted and maintained by Guralp, simplifying hardware and networking demands



## END-TO-END SEISMIC MONITORING SOLUTIONS

If you prefer a hands-off approach, we offer a complete turn-key seismic monitoring solution tailored to your project. You choose the level of service you need, and we take care of everything else. From initial planning to post-completion analysis, we provide full support throughout the entire project lifecycle.

Our comprehensive services include:

### CUSTOMISED NETWORK DESIGN

We work with you to design a seismic monitoring network that meets your project's technical, regulatory, and geographic requirements.

### INSTRUMENTATION SUPPLY

We provide industry-leading broadband sensors and supporting equipment, optimised for your specific monitoring environment.

### BASELINE MONITORING ASSESSMENT

Prior to operations, we conduct a detailed assessment to establish natural seismicity levels, forming a benchmark for ongoing evaluation.

### COMPLIANCE MONITORING DURING OPERATIONS

Our systems ensure real-time tracking and reporting, helping you stay compliant with regulatory thresholds and safety protocols.

### NETWORK MANAGEMENT

We manage the health and performance of your seismic network, including routine checks, maintenance, and system optimisation.

### DATA PROCESSING, REPORTING, AND ARCHIVING

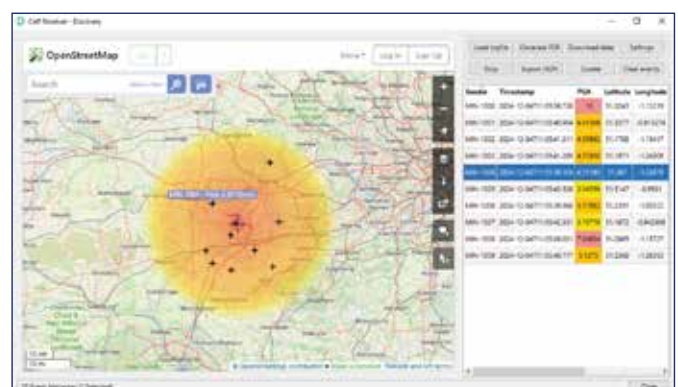
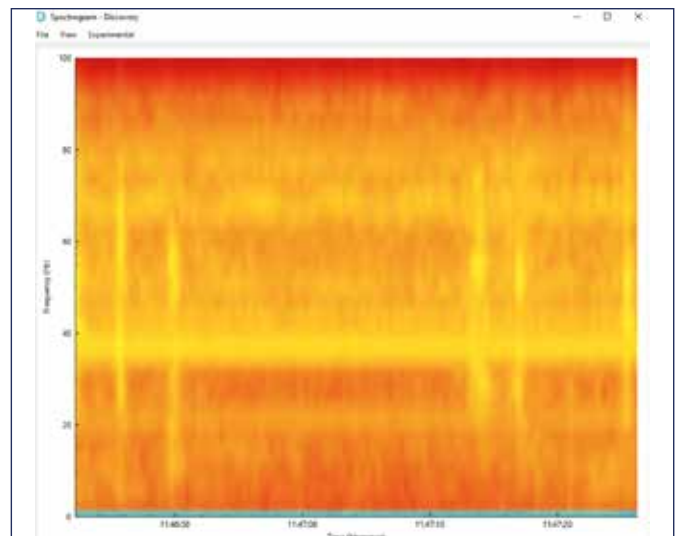
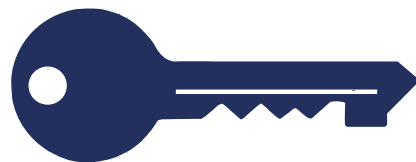
Seismic events are automatically and expertly processed into clear reports, intuitive shake maps, and delivered via instant email or SMS alerts. All data is securely archived and accessible for review or compliance audits.

### POST-COMPLETION ASSESSMENT

Once operations are complete, we conduct a final assessment to compare seismicity before, during, and after the project.

### DECOMMISSIONING

Our team handles the safe and efficient removal of all monitoring equipment, restoring the site as needed.



# THE IMPORTANCE OF BROADBAND.

BROADBAND DATA IS CRITICAL FOR ACCURATE MAGNITUDE ESTIMATION, WHICH IS PARTICULARLY RELEVANT FOR COMPLIANCE MONITORING.

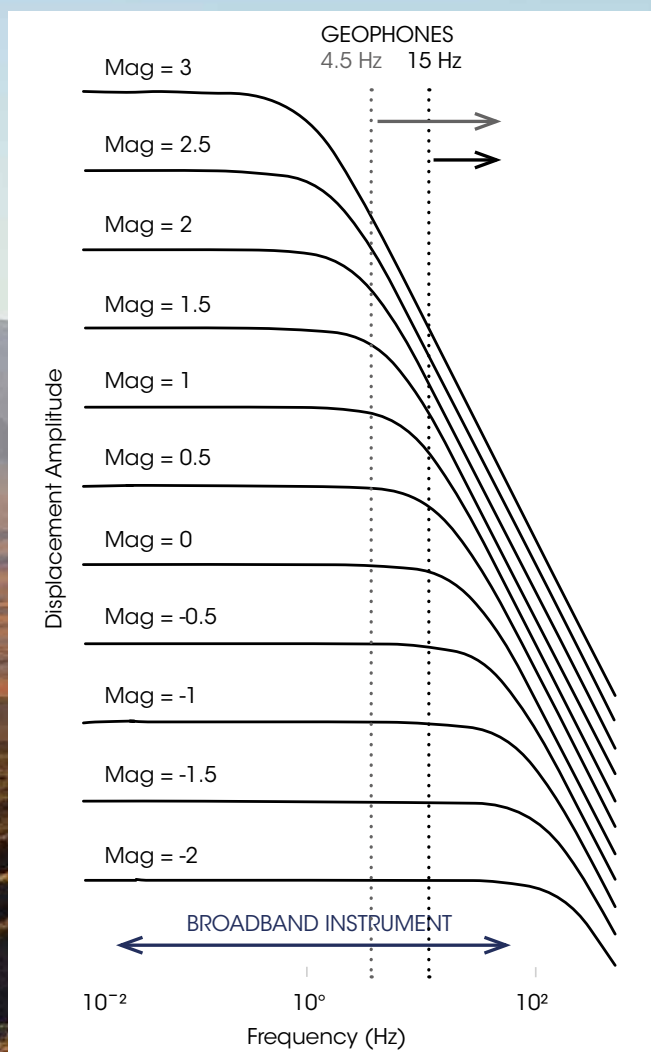
True broadband capability is essential for the accurate magnitude estimation required by traffic light schemes used to manage induced seismicity.

Earthquake magnitudes are derived from displacement spectra—data that only broadband instruments can fully capture. Unlike limited-range geophones, broadband sensors record the complete spectrum, delivering robust and reliable magnitude estimates.

Viegas et al. (2012)\* show that using data from geophones rather than broadband sensors can lead to measurement errors of as much as 0.6 magnitude units, crucial when operating in regulated areas.

DIAGRAM 2 COMPARISON SHOWING GÜRALP BROADBAND INSTRUMENT AND GEOPHONE RESPONSES

\*Viegas G., Baig A., Coulter W., and Urbancic T., 2012. Effective monitoring of reservoir-induced seismicity utilizing integrated surface and downhole seismic networks: First Break 30, 77-81



## THE FULL ENERGY SPECTRUM

Earthquake magnitude is directly calculated from ground displacement. As magnitude increases, so does the proportion of low-frequency energy – frequencies that traditional high-frequency geophones cannot accurately capture.

Broadband seismometers, however, are designed to record these low frequencies, enabling precise and reliable magnitude estimation. Scientific studies have shown that using geophones can result in underestimating magnitudes by up to 0.6 units, a critical error in regulated environments.

## DETECT AND LOCATE

Understanding whether an earthquake is natural or induced (e.g., by fluid injection) begins with accurately determining its hypocenter. This depends on clearly identifying S-waves, which are more prominent in broadband recordings.

S-waves appear clearer on broadband data, making it easier to distinguish near-local events from regional events, reducing the risk of data interpretation errors. S-waves are especially vital for microseismic monitoring because they carry 5 to 15 times more energy than P-waves.

## COMPREHENSIVE SEISMIC MONITORING

Broadband instruments record the full spectrum of seismic activity - shallow to deep, small to large - producing the most complete event catalogue available. This is vital for assessing reservoir changes, planning baseline monitoring, and designing high-resolution networks for future drilling or injection operations.

## DETERMINE COMPLEX FAULTING BEHAVIOUR

Earthquakes have complicated rupture mechanics. For example, induced events may have highly non-double couple mechanisms. Moment Tensor inversion is the tool of choice for understanding these mechanisms—but it requires low-frequency data to be effective.

Broadband seismometers capture the full energy release across the frequency range, making them the optimal solution for characterising both natural and anthropogenic seismic events.



# ARTIUS

## DIGITAL BROADBAND NODES FOR LARGE N ARRAYS

### KEY FEATURES

- > 30 s to 200 Hz
- > Flexible power options, including lithium power packs
- > Seismometer with integrated digitiser and internal GNSS timing
- > Push deployment
- > Wireless configuration via Bluetooth



### NODAL DEPLOYMENT, RESEARCH GRADE RESULTS

Artius redefines what's possible in portable seismology. This three-component digital broadband seismometer combines research-grade performance with rugged, compact design – perfect for dense deployments in medium to high-noise environments.

With a true broadband response range of 30 seconds to 200 Hz, Artius is engineered for rapid, reliable deployment. Whether pushed or staked into the ground, its built-in GNSS and internal digitiser streamline setup – requiring only a single port connection for external power.

Levelling is quick and precise thanks to the integrated bubble level, while the GüVü Bluetooth App ensures smooth field operations. Configure the sensor, monitor real-time waveforms, and check orientation, temperature, and humidity – all from your mobile device.

Despite its powerful capabilities, Artius remains impressively compact at just 80 mm x 80 mm x 105 mm. Its hard-anodised aluminium casing is environmentally sealed, ready to withstand even the harshest field conditions.

### RAPID DATA DOWNLOAD

An eight-capacity docking station is used for testing, configuration, mass data validation and download.

Intuitive Artius dock software automates pre and post deployment workflows for easy handling of the docked nodes. Prior to deployment, the software allows for the mass formatting of the sensor SD cards and verifies performance by automating huddle test procedures. Once the Artius sensors are inserted into the dock, the software automatically begins to download the miniSEED and metadata files from the sensors.

Data is locally recorded on a fixed 64 GB microSD card in miniSEED (with metadata stored in Station XML and dataless SEED formats).





# CARBON CAPTURE, UTILISATION, AND STORAGE (CCUS): SAFE, RELIABLE MONITORING

CARBON MANAGEMENT CANADA (CMC) NEWELL COUNTY FACILITY IN ALBERTA, CANADA (IMAGE COURTESY OF MAURICE SHEVALIER)

## SAFE, RELIABLE MONITORING

CCUS (Carbon Capture, Utilization, and Storage) is a rapidly advancing technology aimed at reducing CO<sub>2</sub> emissions through underground storage. Once used primarily for enhanced oil recovery, it is now a key long-term solution for carbon reduction both onshore and offshore. Microseismic monitoring is essential to guarantee that CO<sub>2</sub> injection and storage are carried out safely and effectively.

## PROVEN MONITORING SYSTEMS

Since 2008, our cutting-edge instrumentation has been trusted on numerous projects across North America and Europe to monitor seismic activity around carbon injection sites. Our systems combine sensitive event detection with ultra-low latency data and rapid triggering capabilities, ensuring operations remain within safe, predefined limits.

## TAILORED SOLUTIONS FOR DIVERSE ENVIRONMENTS

Our tailored systems are suitable for all injection environments - onshore subsurface, including vertical seismic profiling (VSP), as well as offshore deployments.

Our borehole instruments are ideal for sites prone to surface noise while our ocean bottom seismometers support both active source and passive imaging.

Leveraging broadband systems for active source imaging delivers unparalleled insights into deep subsurface structures, helping you make informed decisions with confidence.

### CASE STUDY 1:

#### UK Geoenergy Test Bed

- > The Radian is being utilised by the British Geological Survey as part of the UK GeoEnergy Test Bed (GTB) to monitor and improve understanding of fluid flow through natural subsurface pathways.
- > A string of six interconnected Radians provides vertical profiling around the injection site with a maximum of eight units able to connect in a single string.
- > The Radian will detect and monitor small changes in the subsurface at the GTB as part of the suite of monitoring technologies deployed onsite.

### CASE STUDY 2:

#### Carbon Management Canada (CMC)

- > The University of Oxford and the University of Bristol worked on a joint project with CMC to monitor CO<sub>2</sub> injection at the CMC test site using broadband seismometers.
- > Research informing how to establish safe CO<sub>2</sub> storage monitoring protocols within a regulatory framework.
- > Seven Gralp seismometers were deployed to monitor baseline seismicity one year prior to testing.
- > 335 events exceeding M4.5, 556 regional events and no local events were detected during baseline monitoring.

### CASE STUDY 3:

#### Horda Platform, offshore Norway

- > Gralp instrumentation selected for HNET project to assess potential for seismic hazard in advance of injection activity.
- > 3T-120 posthole instruments deployed in a nine station array on Holsny, an island on the west coast of Norway.
- > Sensors deployed in land-based array, tuned to offshore monitoring, to test potential for cost effective alternative to marine-based monitoring.
- > Instruments deployed in shallow posthole sites to mitigate against ambient noise.
- > Improved seismic event monitoring in the target area by lowering the event detection threshold; providing initial locations from back azimuth and SP-wave arrival-time difference; and improving event location capability using back-azimuth measurements for events.



# GEOTHERMAL POWER PLANT MONITORING

KRAFLA GEOTHERMAL POWER PLANT, ICELAND

## ACCURATE HYPOCENTER LOCATION AND SUBSURFACE IMAGING

Broadband seismometers provide accurate hypocenter locations and, through advanced seismic tomography, enable detailed imaging of subsurface structures critical to geothermal regions.

We offer comprehensive baseline seismicity surveys before, during, and after operations - with options for real-time data processing and intuitive traffic light displays to provide immediate operational feedback.

Our geothermal monitoring systems are proven, with installations delivering reliable performance for over fifteen years.

### CASE STUDY 4:

#### Iceland Geothermal Monitoring, University of Cambridge

- > Geothermal fields are commonly situated close to the boundaries of the earth's tectonic plates making it difficult to determine whether earthquakes occur due to natural processes or geothermal activities caused by humans.
- > A dense array of 24 Güralp seismometers monitored the Krafla volcanic region of Iceland.
- > Over 3,000 events were detected in the 14 months of the array's operation.
- > Locations of the earthquakes show that most were located beneath the Krafla caldera in the uppermost 2-3 km of the crust.
- > Inversion of earthquake focal mechanisms show that many seismic events have complex source mechanics. The presence of some implosive source mechanisms are consistent with fracturing due to fluid migration.
- > The majority of earthquakes were interpreted to coincide spatially with the location of the main geothermal field. A small number of events were also associated with drilling of geothermal boreholes. A number of small earthquakes were found to occur along fissure swarms; these events are likely to have been caused by natural tectonic processes.

### CASE STUDY 5:

#### Deep Geothermal Systems, Germany Goethe-University Frankfurt

*"The signal to noise ratio is impressively high considering the distance to the array and the relatively small magnitude."*

Dr. Philip Hering, Institute for Geosciences, Geophysics  
Goethe-University Frankfurt

- > Rheinland-Pfalz region of Germany is the location of several geothermal power plants. Goethe-University Frankfurt installed a seismic array system to provide large-scale monitoring of seismicity in the region within the framework of a publicly-funded geothermal project.
- > The Landau and Insheim geothermal power plants are separated by just 4 km.
- > Specific array pattern functions are being developed to detect and identify induced earthquakes in the directional beam of the array.
- > Nine Güralp Certimus seismic stations were deployed powered solely by solar panels with no loss of performance, even during darker winter months.
- > The array is collecting data to establish a solid data base for classification algorithms.
- > If successful, the array may be integrated with the existing conventional seismic networks operated by the regional authorities and the geothermal companies that provide the traffic light warning system for the geothermal plants.



INSTALLED CERTIMUS SEISMOMETER  
CREDIT:  
DR. PHILIP HERING,  
GOETHE-UNIVERSITY  
FRANKFURT

# HYDRAULIC FRACTURE MONITORING

AERIAL VIEW OF HYDRAULIC FRACTURE OPERATIONS

## ENSURE COMPLIANCE WITH ADVANCED MICROSEISMIC MONITORING

As regulations on hydraulic fracturing tighten, real-time monitoring of microseismic activity is crucial. Operators must adjust injection rates based on seismic data, often using a traffic light system tailored to local regulations.

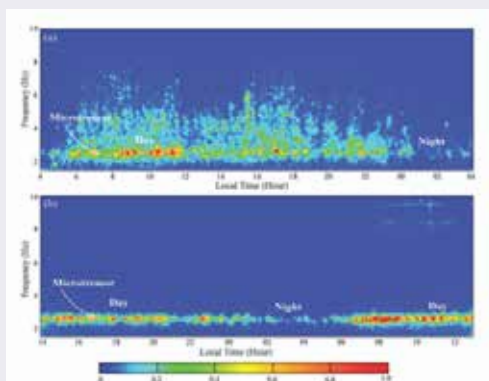
## OVERCOME THE LIMITATIONS OF TRADITIONAL SYSTEMS

While dense surface geophone arrays can be costly and may underestimate event magnitude, sparse broadband arrays offer a cost-effective, high-confidence solution.

EXAMPLE MONITORING THRESHOLDS FOR TRAFFIC LIGHT SYSTEMS



WE CAN PROVIDE DETAILED REPORTS OF DETECTED EVENTS AND THE OPERATIONAL STATUS OF THE ARRAY



These arrays also enable pre-operation baseline studies, ensuring a strong operational foundation.

## TURNKEY SOLUTIONS FOR FLUID INJECTION OPERATIONS

Partnering with global leaders, we deliver turnkey monitoring packages tailored to the fluid injection industry – helping you stay compliant, safe, and efficient.

### CASE STUDY 6:

#### Oklahoma Fracture Monitoring

- > A small array of Guralp seismometers monitored a hydraulic fracture stimulation in Oklahoma, U.S.
- > Using broadband data and an advanced event location method, we were able to detect five times the number of earthquakes than conventional analyses.
- > Our results showed that using advanced event location methods with broadband data is critical for compliance with regulatory traffic light systems that require low frequency magnitude thresholds.

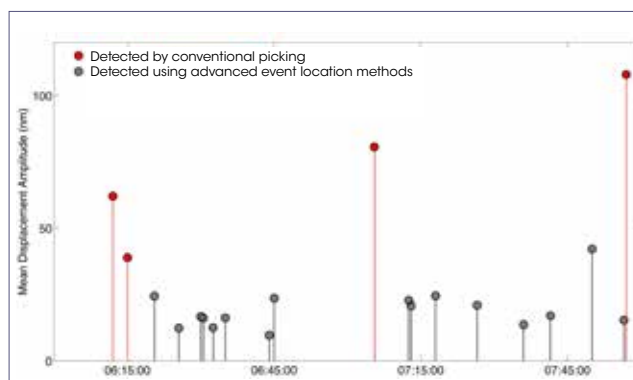


DIAGRAM 1: MEAN DISPLACEMENT AMPLITUDES OF EVENTS DETECTED DURING TRIALS. THE BROADBAND INSTRUMENTATION DETECTS SMALLER EVENTS MISSED BY CONVENTIONAL ANALYSIS.



# PERMANENT RESERVOIR MONITORING

STATION INSTALLATION IN KASHAGAN

## MAXIMISE HYDROCARBON RECOVERY WITH 4D SEISMIC DATA

4D seismic data provides valuable insights into how reservoirs evolve over time, unlocking potential to enhance hydrocarbon recovery.

## ADVANCED BROADBAND SYSTEMS FOR RESERVOIR INTEGRITY

Whether using active or passive sources, our broadband systems offer critical data on cap rock integrity and wellbore stability. Integrated into a reservoir integrity management plan, these systems help maximise production and protect your assets.

## COST-EFFECTIVE PASSIVE SEISMIC IMAGING

Passive seismic imaging is a proven, cost-effective method to monitor reservoir changes. This technology helps optimise production and ensures safe, efficient management of future reservoir development.

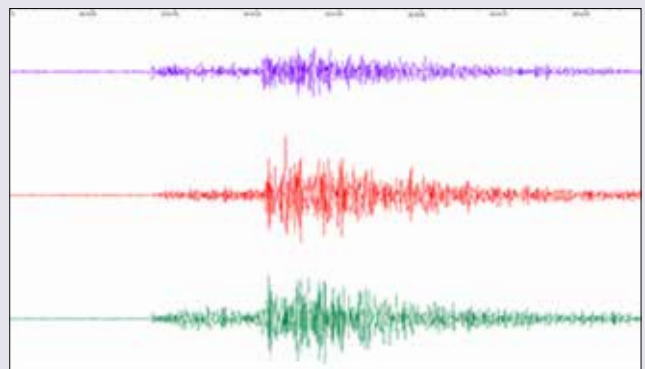


GÜRALP FIELD SERVICE ENGINEER INSTALLING A BOREHOLE STATION

## CASE STUDY 7:

### Kashagan Permanent Reservoir Monitoring, NCOC, Kazakhstan

- > GÜralp installed a seismic network of digital 3T borehole sensors in Kashagan Field. The sensors were deployed both onshore and offshore.
- > All instruments are located approximately 100 m below the surface. Each sensor is fixed in place using a dedicated hole-lock system.
- > Due to the very high surface noise resulting from the working marine environment, borehole sensors were selected to ensure data with very high signal to noise ratio, leading to better quality waveforms.
- > The monitoring was established to satisfy Kasak regulatory requirements.
- > GÜralp delivered a full turnkey solution to NCOC that consisted of:
  - Recorded data was processed to determine seismic event locations and magnitudes.
  - Automated daily email alerts.
  - Regular detailed reports about the operational status of the network and detected events.



THREE-COMPONENT WAVEFORMS REPRESENTING A RECORDED LOCAL M2.3 EVENT LOCATED 80KM AWAY FROM KASHAGAN FIELD



# MARINE INSTRUMENTS

## AUTONOMOUS AND CABLED MARINE SEISMIC SYSTEMS

### AQUARIUS

For offshore deployments Aquarius offers a flexible solution suitable for both baseline and operational monitoring, without cables, for up to 18 months.

Fully autonomous and highly configurable, Aquarius is also equipped with acoustic data telemetry. For monitoring scenarios, a list of events (detected using STA/LTA triggers) can be sent to the surface in near real-time. More detailed data can then be retrieved by the operator as desired. Free-fall deployment and acoustic release recovery allow for multiple deployments at different sites.



***Aquarius and Maris  
are both fully  
operational at  
 $\pm 90^\circ$  for easier  
deployment on the  
seafloor, without  
gimbals***

### MARIS

For permanent installations, Maris offers the same sensor versatility as Aquarius with the real-time data communication associated with cabled installations.

Maris offers versatile deployment options. If desired, multiple instruments can be strung together via a single cable. Triggered alert data can be sent at ultra-low latency for virtually instantaneous monitoring and alert applications, achieving network transmission in as little as 40 milli-seconds.





# BOREHOLE INSTRUMENTS

GET CLOSER TO THE SUB-SURFACE

## 3T/5T BOREHOLE

The Güralp 3T/5T combines our renowned 3T broadband seismometer with the proven 5T strong-motion accelerometer. This allows for simultaneous monitoring of both weak and distant seismic events, and near-field, high intensity shaking, in a single instrument.

The 3T is the instrument of choice for an extensive number of nuclear test ban treaty monitoring arrays around the world, with thousands of systems deployed over the past thirty five years.

- > Total realised dynamic range of over 200 dB
- > Exceptionally low noise floor
- > Digital and analogue systems available



## RADIAN

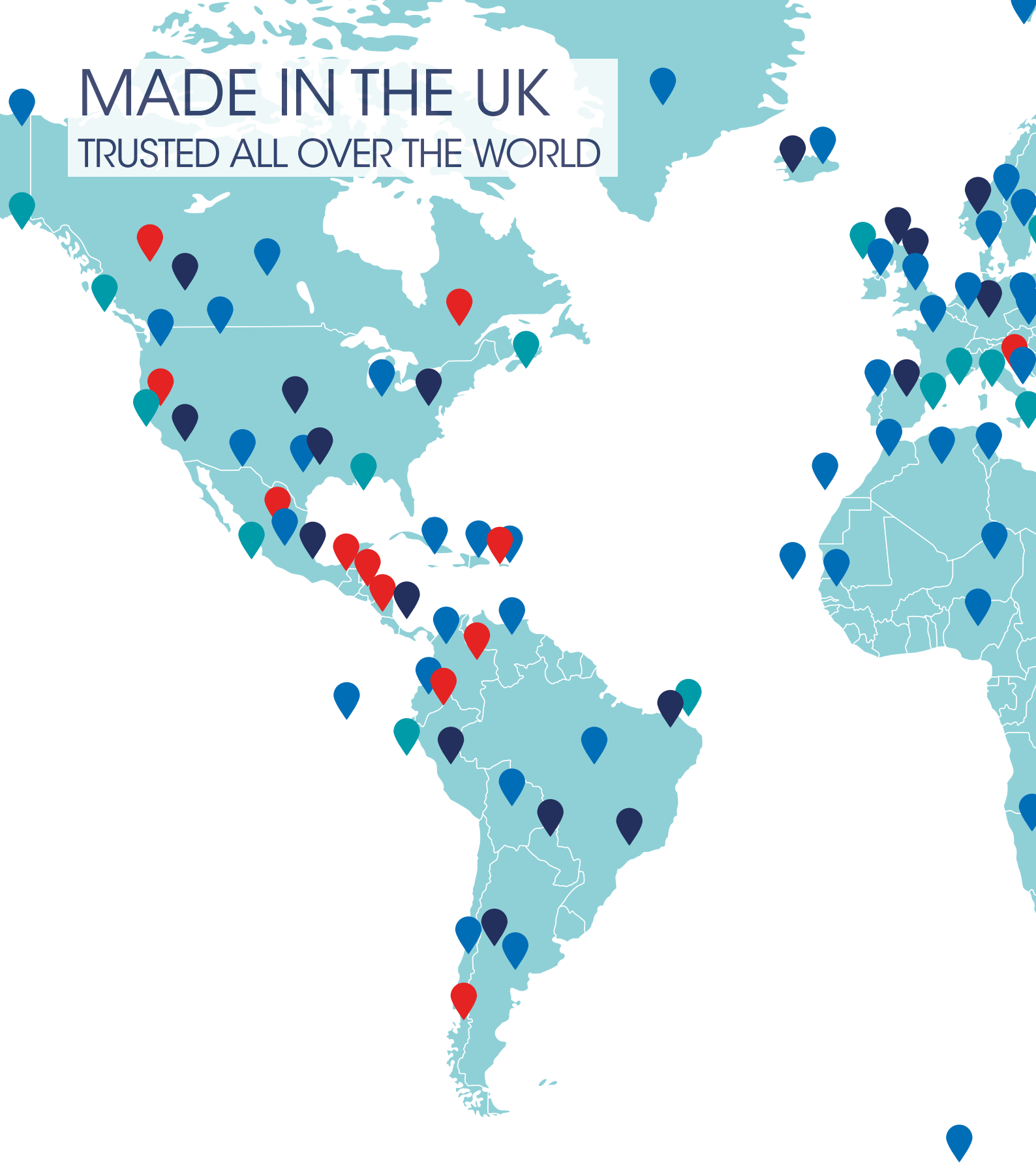
With an ultra-wide response, an adjustable high-pass frequency corner and the capability of operating at any angle, Radian offers up opportunities for subsurface deployments that would otherwise prove too challenging or unpredictable. Ideally suited to microseismic monitoring, if desired, multiple instruments can be strung together to form vertical arrays.





# MADE IN THE UK

## TRUSTED ALL OVER THE WORLD



### MICROSEISMIC

Projects range from energy production activities such as monitoring geothermal energy plants to traffic light alerting for CO2 injection and hydraulic fracture operations.

### MARINE SEISMOLOGY

Our ocean bottom seismometers are selected for national instrument pools, earthquake monitoring and early warning networks, and ground-breaking SMART cable projects.





#### REGIONAL OR NATIONAL ARRAYS

Güralp instrumentation forms the backbone of regional and national monitoring arrays around the world, monitoring seismic and volcanic activity as well as nuclear tests.

#### EARLY WARNING

Rapid processing and transmission requirements combined with robust data quality are the basis for selecting our instrumentation for earthquake early warning networks around the world.



For further information please  
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#### ISO9001:2015

We operate a quality management system in accordance with ISO 9001:2015 for the scope of:

'Design and manufacture of low noise broadband seismometers, accelerometers, digitisers and networking equipment for science and engineering. Software Design and development.'

