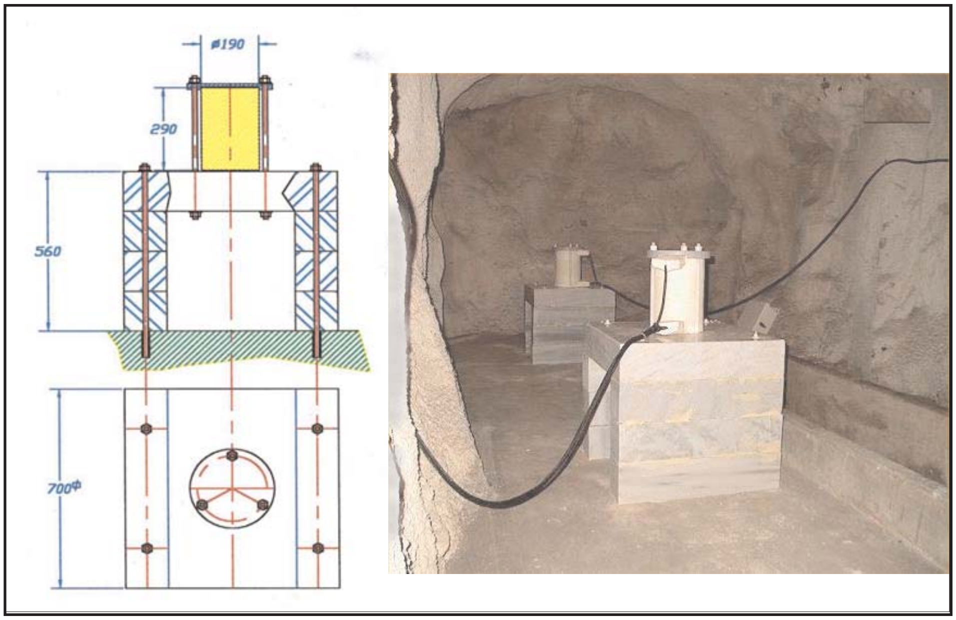
SuperGrad & ISGR

Earthquake Prediction Instrumentation

The SuperGradiometer system is designed for earthquake prediction applications that require the most demanding survey specifications.

Key benefits include:

- **Most sensitive gradiometer available (1 fT/m) for detection of subtle signatures**
- **Most sensitive magnetometer available**
- **Elimination of cultural effects**
- **Elimination of diurnal effects**
- **Minimal 1/f noise (in contrast to electromagnetic methods)**
- **Complementary gradiometer and total field magnetic data for integration with radon data**
- **Standalone or Integrated SuperGrad / Radon System (ISGR) options**
- **Efficient remote control operation / interrogation using RS-232**
- **Flexibility to enable real-time transmission via RS-232 and modem to satellite and phone links**



SuperGradiometer installed near Eilat, Israel within the framework of a joint Canada-Israel research project. Sensors and mounting platforms are shown.

Each year, earthquakes injure more than 17,000 people and cause more than $40 billion in property and environmental damage around the world. Driven by the goal of mitigating these damages, many international researchers are pursuing earthquake monitoring and prediction studies. These efforts focus on evaluating event time, magnitude and location for implementation of early warning systems.

Historically, work has focused on seismic methods based on the known association of seismicity with earthquakes. However, earthquakes are complex phenomena and other methods are also being actively investigated, including GPS, Strong Motion Sensors, Electromagnetics, etc.

Promising New Approaches

Gradiometry is emerging as a promising method due to reports of piezomagnetic effects prior to large earthquakes. The approach is based on gradiometric monitoring (i.e. the process of using total field gradients to measure, determine, separate and eliminate the different patterns of the geomagnetic field perturbation).

Earthquake research studies show large amplitude magnetic responses weeks and hours before events. Smaller events appear to exhibit less coherent patterns; likely due to the lack of sensitivity of traditional magnetic instruments.

SuperGrad - GEM's Latest Technology

GEM's new SuperGradiometer is designed to improve detection of subtle responses and potentially lower the threshold of detectable earthquakes.

The GSMP-20GS3 was developed with the Russian research group of Dr. E. Alexandrov in response to the United State Geological Survey's (USGS) requirement for an ultra-high sensitivity magnetic gradiometer. It is the highest sensitivity total field measuring device ever developed with a 0.05 pT root-mean-square (rms) sensitivity at a sampling rate of 20 Hz (averaged over a 1 second interval). This ultra-high sensitivity is well over an order-of-magnitude more sensitive than any other system available.

For earthquake research applications, the GSMP-20S3 can achieve gradient sensitivities of 1fT/m (10-15 T/m) with a sensor spacing of 50m - a major advantage over traditional long-baseline measurements (i.e. total field with reference station for removal of diurnals) which have sensitivities on the order of 1nT. The GSMP-20S3 also minimizes cultural noise (i.e. from nearby infrastructure), and minimization of 1 / f noise that typically degrades results from other types of measurements (ex. Electromagnetic). Note that f is the frequency of the piezomagnetic signal from the event.

Optically Pumped Potassium Technology, Acquisition and Analysis

Key technologies include optically pumped Potassium sensors for ultra-high sensitivities. The system is typically arrayed with a vertical sensor and another two horizontal sensors oriented in an "L-shaped" pattern. Horizontal sensors are located at specified distances (ex. 50m or 100m) for maximum sensitivity. A GPS receiver records Universal Time.

Raw data are acquired at 20 samples per second along with filtered (running average) 1 sample per second data. This very large volume data is transmitted to a commercial computer and formatted in 1 hour files for transfer via telephone, cell phone, or Internet to the central station. A standard program, such as Laplink, is used for remote control operation.

Subsequent data analysis is based on different techniques including visualization of events for time prediction and calculation of other parameters (ex. ratios) to help evaluate geometry or direction.

Integrated SuperGrad / Radon (ISGR) Option

GEM offers the Integrated SuperGrad / Radon system (ISGR) as an option for researchers seeking to integrate two types of information-rich, independent data into joint interpretations.

In a joint project with ISORAD, Israel Geologic Survey, Survey of Israel and GEM, SuperGrad results are being integrated with Radon data from the Dead Sea Rift, Israel. In its first year and 3 months of operation, the ISGR prototype has acquired over 5.25 billion readings - the highest sampling of magnetic data acquired by any organization over this length of time. Initial results show a sensitivity of 0.1 pT which is modulated by weak diurnals due to the surrounding rocks - a reflection of initial installation in a tunnel setting. Diurnals can be suppressed - increasing background noise to 1 pT peak-to-peak or about 0.25 pT root mean square (rms).

Radon studies to date have examined the temporal relationship between hundreds of weak earthquakes (M < 4.6) and the start time of 110 Radon flux signals. Earthquakes located within the three pull-apart grabens of the Dead Sea rift valley were found to occur preferentially within the first 3 days after Radon start time.

These results demonstrate a statistically significant correlation between week earthquakes and Radon flux. In contrast, but in agreement with geological reasoning, earthquakes outside the Rift do not show a connection to anomalies recorded within. Ultimately, integration of data from gradiometric sources will serve to complement the Radon studies both inside and outside of the Rift.

Configuring SuperGrad and ISGR

For optimal results, the system should be sited with sensors in a magnetically quiet region close to the fault system under investigation. Israeli partners recommend consultation with the geological team to most effectively site the sensors.

In addition, the sensors should be sited in an enclosed structure and immobilized to ensure repeatability of data throughout the monitoring period. A further consideration is how many sensors to use (3 or 4) and their baseline distances.

Research in Progress

Currently, Israeli team members are planning to install a second system to complement the existing installation.

A third system was recently installed at a Geological Survey of Canada observatory site in Ottawa, Canada. Data will be analyzed prior to implementation at other sites around the world. For more details on research results, contact GEM.

SuperGrad Specifications

Performance

Resolution:	0.001 pT for up to 20 readings per second
Intrinsic Noise Density:	0.05 pT / Hz $^{1/2}$
Absolute Accuracy:	0.2 nT.
Time Base Stability:	0.01 ppm over -40°C to + 55°C
Long Term Stability:	Better than 1 pT / day.
Dynamic Range:	10,000 to 100,000 nT
Operating Temperature:	-40°C to +55°C
Power Consumption:	22 to 32 V. 12 W average. 40 W maximum.
Tuning:	Wideband system. No tuning.
Sensor Orientation:	45 +/- 3 5 degrees off the magnetic field direction.

Rate of Reading

0.01 to 1000 samples / second

Output:

Analog:	1 channel of magnetic field and 1 channel of gradient data. 1, 10 & 100 pT. 1, 100, 100 nT. 1 µT.
Digital:	Serial RS232C with programmable parameters.
Visual:	Alphanumeric LCD. 11 digit magnetic field. 7 digit magnetic gradient.

Dimensions & Weights

Console:	483 x 89 x 406mm / 6.6 kg
Sensor:	26.3 cm dia. x 23 cm / 6.0 kg
Electronics:	100 x 50 x 100 mm / 1.0 kg
Lamp Assembly:	17 cm x 9 cm dia.
Cable Lengths:	User-specified, 1 - 300m.

Standard Components

GSMP-20S3 console, Potassium sensor with cable, GSMP-20S3 software, RS-232 cable and instruction manual. Optional GPS for precise time values.

For information on ISGR, contact GEM.

GEM Advanced Magnetometers
52 West Beaver Creek Road, 14
Richmond Hill, ON
Canada L4B 1L9
Email: info@gemsys.on.ca
Web: www.gemsys.ca