

Advancing the Practice of Seismology in Iraq

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Abstract

Iraq is located at the leading northeastern edge of the Arabian plate. Its seismotectonic framework is a product of the NE motion of the plate and the continental collision along the Bitlis and Zagros orogenic zones. In late 1970s, the country embarked on the establishment of Iraq Seismographic Network (ISN) consisting of 5 autonomous observatories equipped with a mix of seismic sensors. In early 1990s, the effort came to an ill-fated end, and the first 3 established stations were vandalized. In late 2005, we collaborated on the establishment of the 10 stations North Iraq Seismographic Network (NISN). In 2008, NISN's capability was further enhanced by adding a 5 station circular seismoacoustic array KSIRS. In early 2009, the central government resurrected ISN by establishing a new network of 6 stations. All of the stations established since 2005 are equipped with advanced, three components broadband sensors, and some are also equipped with radio and satellite telemetry. The establishment of the network observatories in the cities of Sulaimaniyah and Erbil, NISN and KSIRS has brought unprecedented advancements to the practice of seismology in Iraq. For example, the ongoing daily updated database of over 11000 seismic events located in Iraq and the surrounding regions.

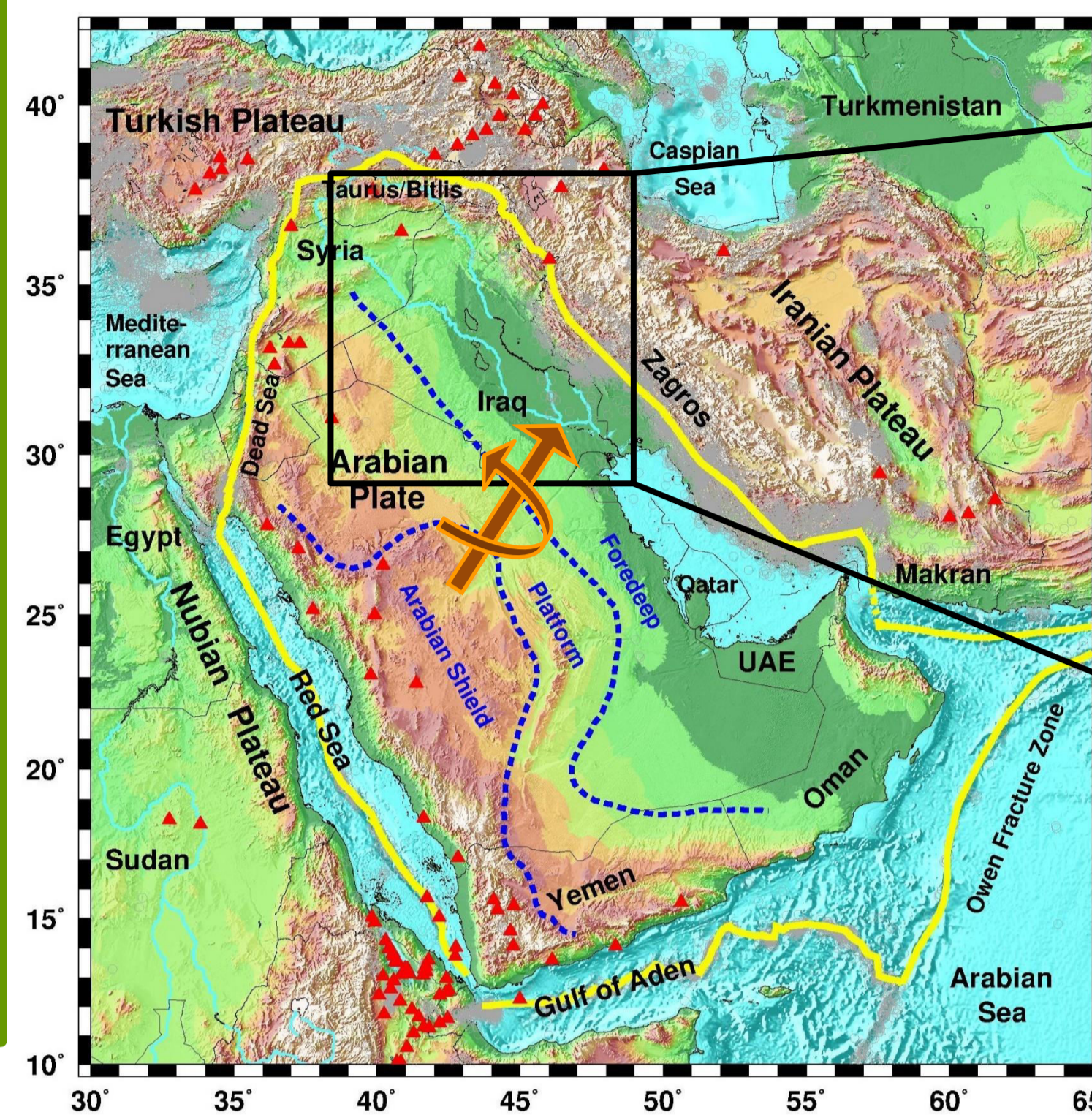


Figure 1. Map of the Arabian plate highlighting its seismically active boundaries (yellow lines) and its physiographic boundaries (blue dashed lines). The Arabian shield, platform, Mesopotamia foredeep and the Zagros-Taurus Bitlis mountain ranges dominate the tectonic framework of the region. The plate's trans-rotational motion relative to Eurasia and Africa (brown arrows) and the continental collision along the Zagros-Taurus Bitlis is a manifestation of the ocean floor spreading along the Gulf of Aden and the Red Sea, and the motion along the Dead Sea transform fault system.

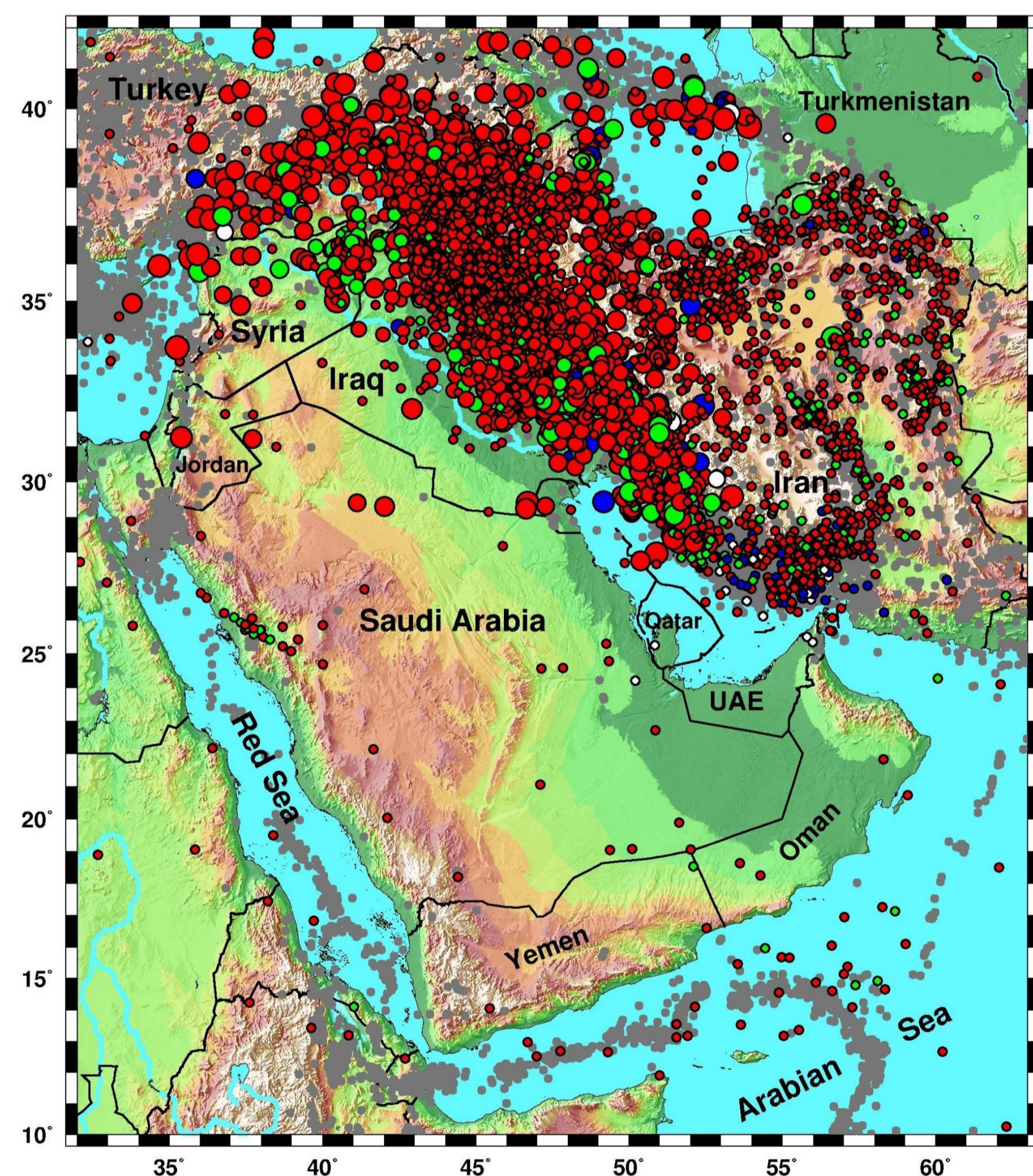


Figure 5. Recent seismicity of Iraq and surrounding regions for the period 1/1/2006 - 4/9/2009. The events are located using waveforms recorded by the NISN, ISN and the Global Seismic Network (GSN) stations in the region, and bulletins published by the Jordan Seismological Observatory (JSO), and the Iranian and Turkish authorities. The number of located events has since increased from about 8000 to over 12000 and seem to follow the same distribution pattern. The events depicted in gray dots (12604) are reported by the NEIC for the period 4/12/1905 - 31/7/2015, and included in this figure for reference. The majority of these events (red dots) are found to occur within the upper 20 km of the crust. Significantly less number of events are found to occur in the lower crust (green dots), whereas events deeper than 50 km seem to occasionally occur in Iran and Turkey rather than the Arabian plate (blue and white dots). The estimated duration magnitudes for the events in this figure range from 2 - 4. Larger magnitude events (5 - 6) are known to occur in Iran and Turkey.

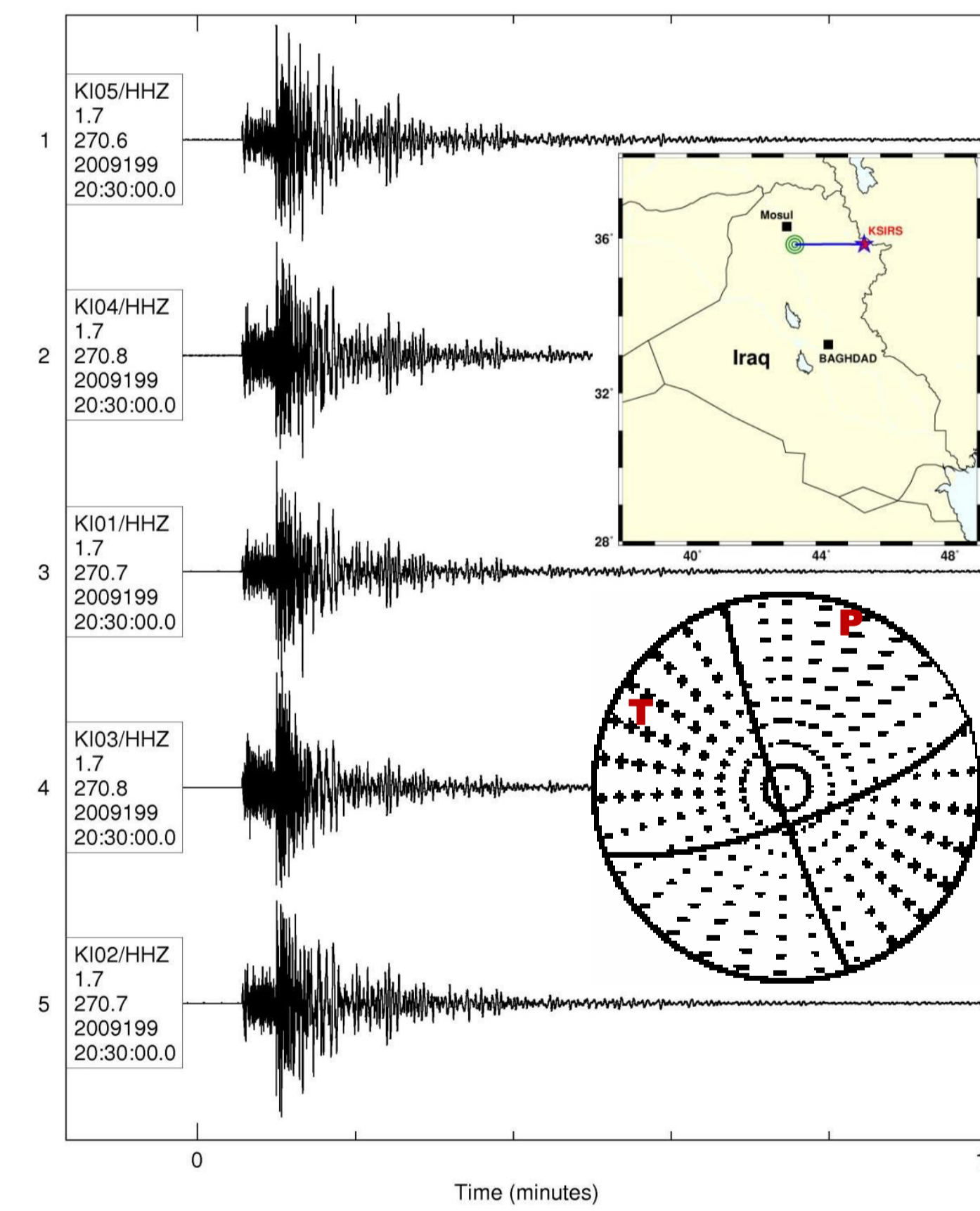


Figure 6. Waveforms of an event recorded at eight of the NISN stations in which the primary regional phases *P_n*, *P_g*, *S_n*, *L_g* are easily identifiable on most traces. This event occurred on 26/12/2005 at 23:15:53.4, 49.1713°N, 49.2201°E, 32 km, *m_b*=5.1. The epicentral distances and azimuths range from about 130-140 km and 2-5°, respectively.

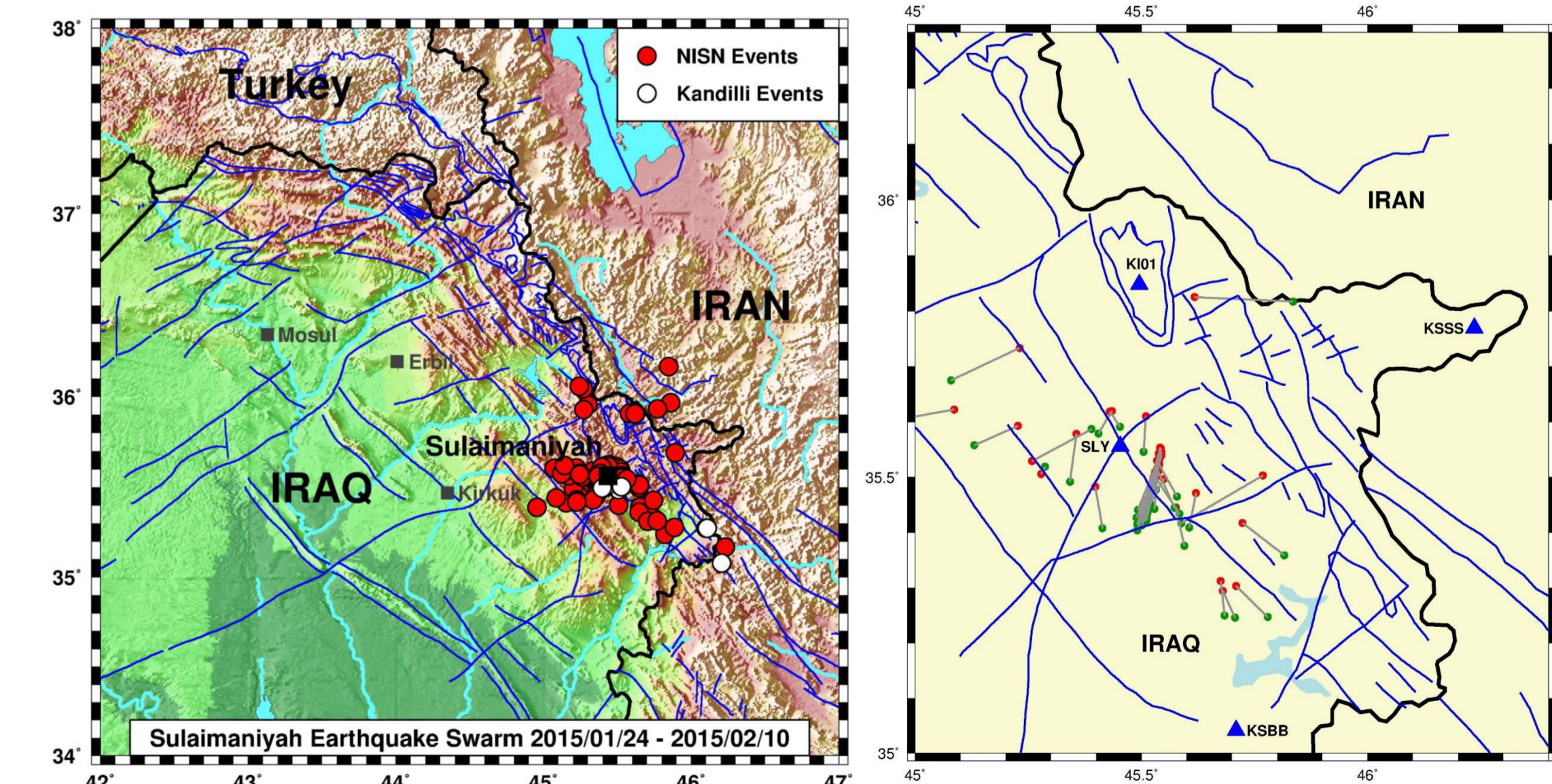


Figure 8. The Sulaimaniyah earthquake swarm of 24/1/2015 - 10/2/2015 recorded by NISN (i.e., array KSIRS, and stations SLY and KSBB). NISN recorded 159 events in this period. The largest is estimated to be 3.6 ML. Some of the larger events were reported by the Iranian Seismological Network (IRSN) and the Turkish Kandilli observatory. Relocation of the larger events (red dots) using the Joint Hypo Determination (JHD) technique resulted in aligning several of the events (green dots) with two semi-orthogonal faults (map to the right).

Figure 2. Map showing the location of the NISN stations, the seismoacoustic array KSIRS, new ISN stations, and data centers at Sulaimaniyah, Erbil and Baghdad Seismological Observatories, SSO, ESO and BSO, respectively. Many of the NISN stations are being relocated and equipped with telemetry system. All the stations are equipped with broadband 3-component STS-2 seismometers and Q330 24 bits digitizers. Stations SLY near Sulaimaniyah and newly established station KHLR near Erbil are sending data via radio and Internet, respectively.

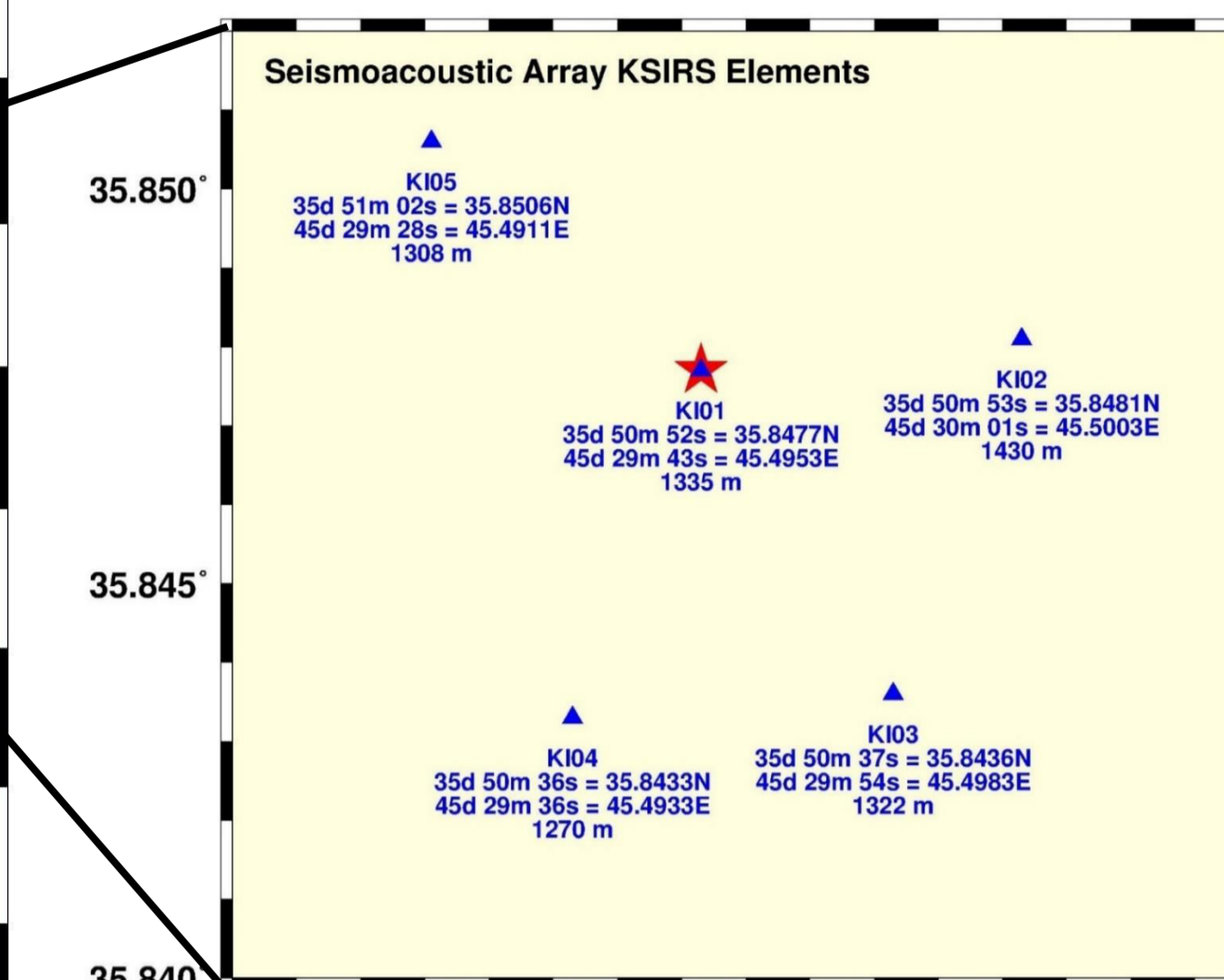
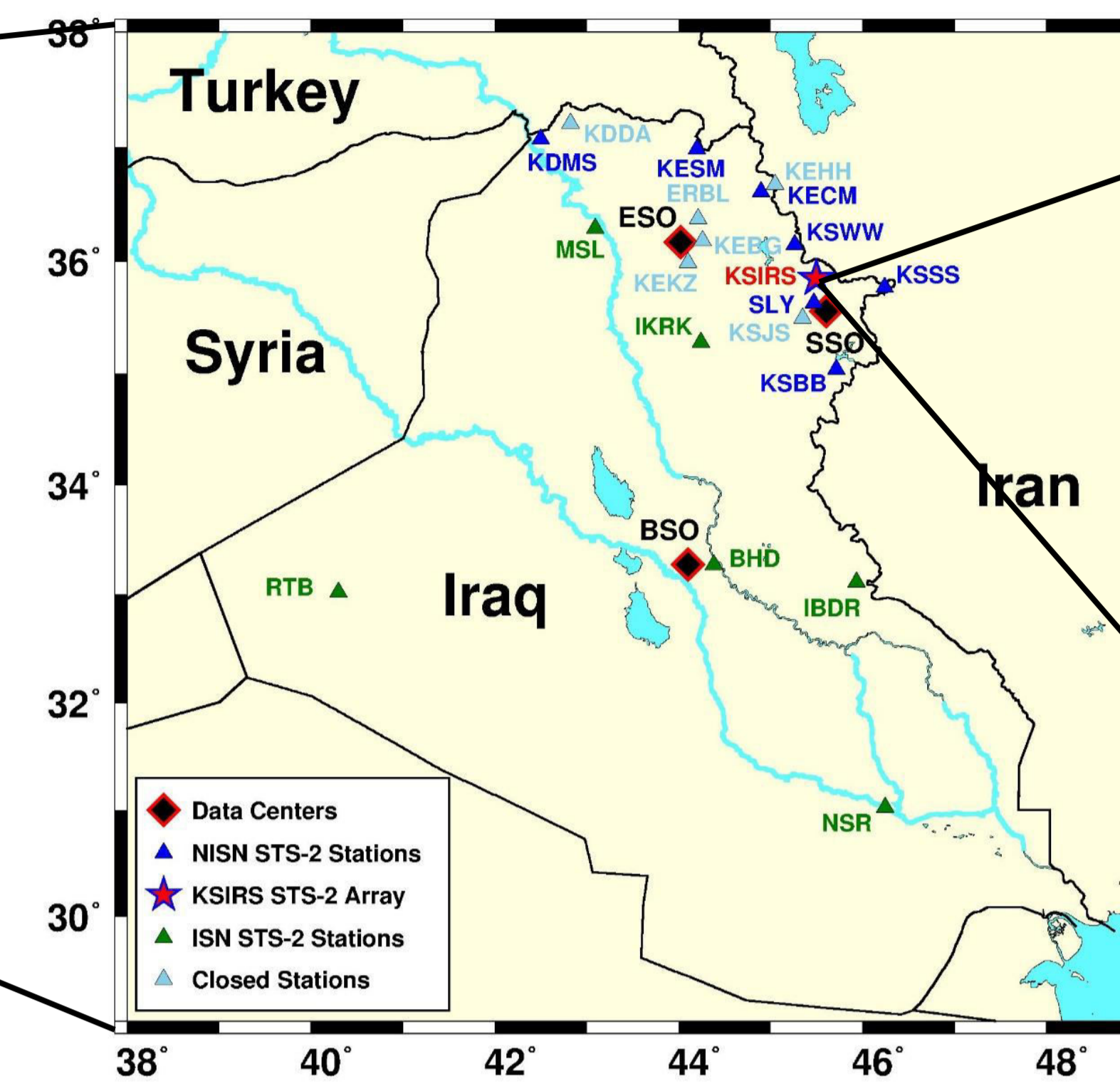


Figure 3. All of the seismoacoustic array KSIRS stations are equipped with Q330HR 26 bits digitizers, Marmots, Chaparral 2.5 sensor, Afar radios and a satellite communication systems. All elements of the array are powered by solar panels.



Figure 4. Pictures showing the seismoacoustic array KSIRS station's vaults, instrumentation, radio and satellite communication, and solar power.

Figure 7. Waveforms of the 18/7/2009 Sharqat earthquake recorded by all elements of the nearby (< 2°) KSIRS array. It is the first major earthquake in Iraq since the deployment of NISN. The origin time of this 5.1 *m_b* event is 20:32:27, its location is (35.8450°N, 43.3490°E), and its depth is 7.4 km. The observed high frequency signals are well recorded by the array with high fidelity, often showing good signal-to-noise out to 30 Hz. The estimated best fitting double couple moment-tensor solution is *M₀*=1.12e+24 dyne-cm, *M_w*=5.3 and depth *Z*=20 km. The strike, dip and rake angles of the two nodal planes in degrees are (NP1: 161, 85, -165) and (NP2: 70, 75, -5). The stations used in the inversion are KSIRS (K101), CSS, MALT, RYAN, ANTO and GNI.

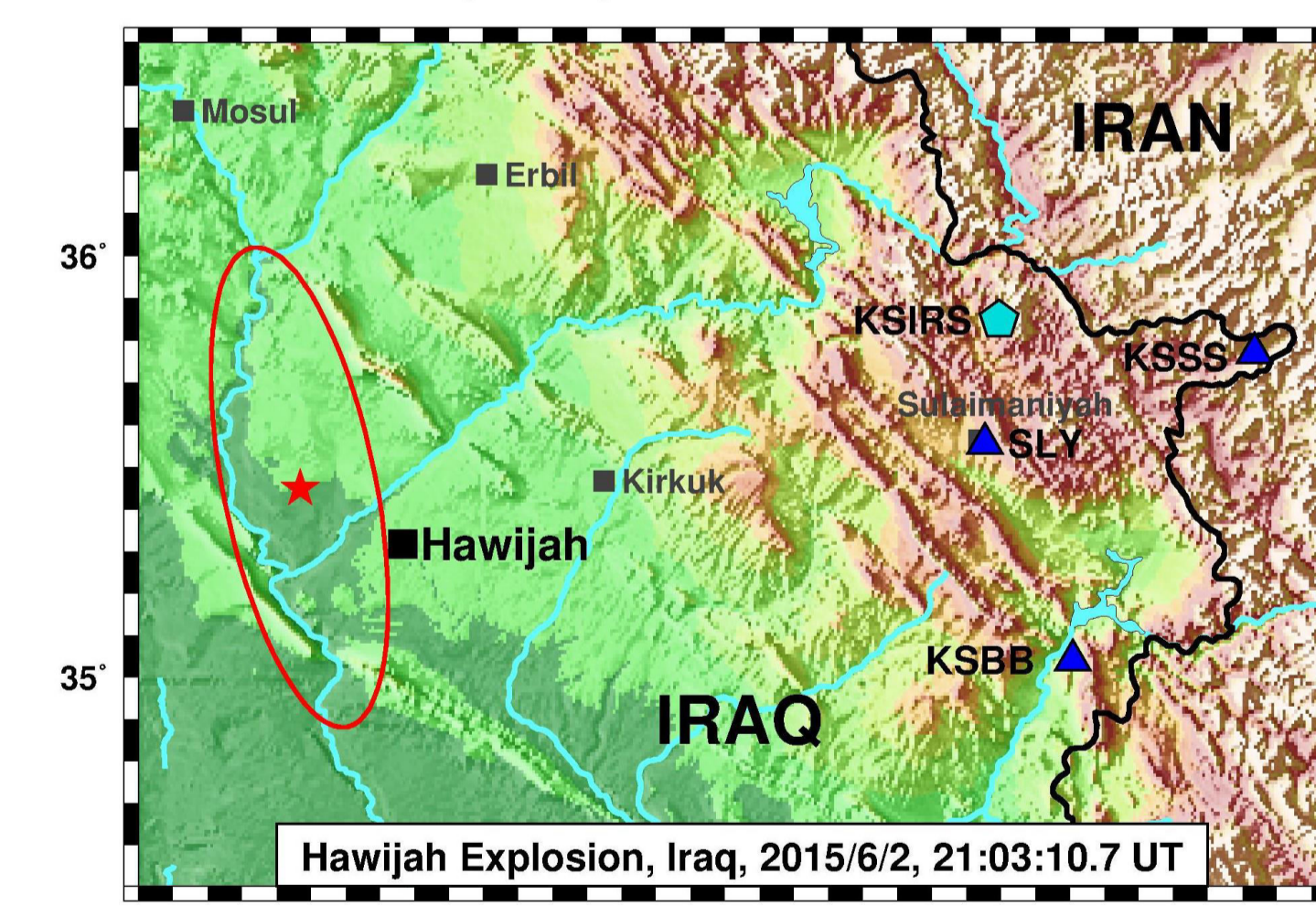
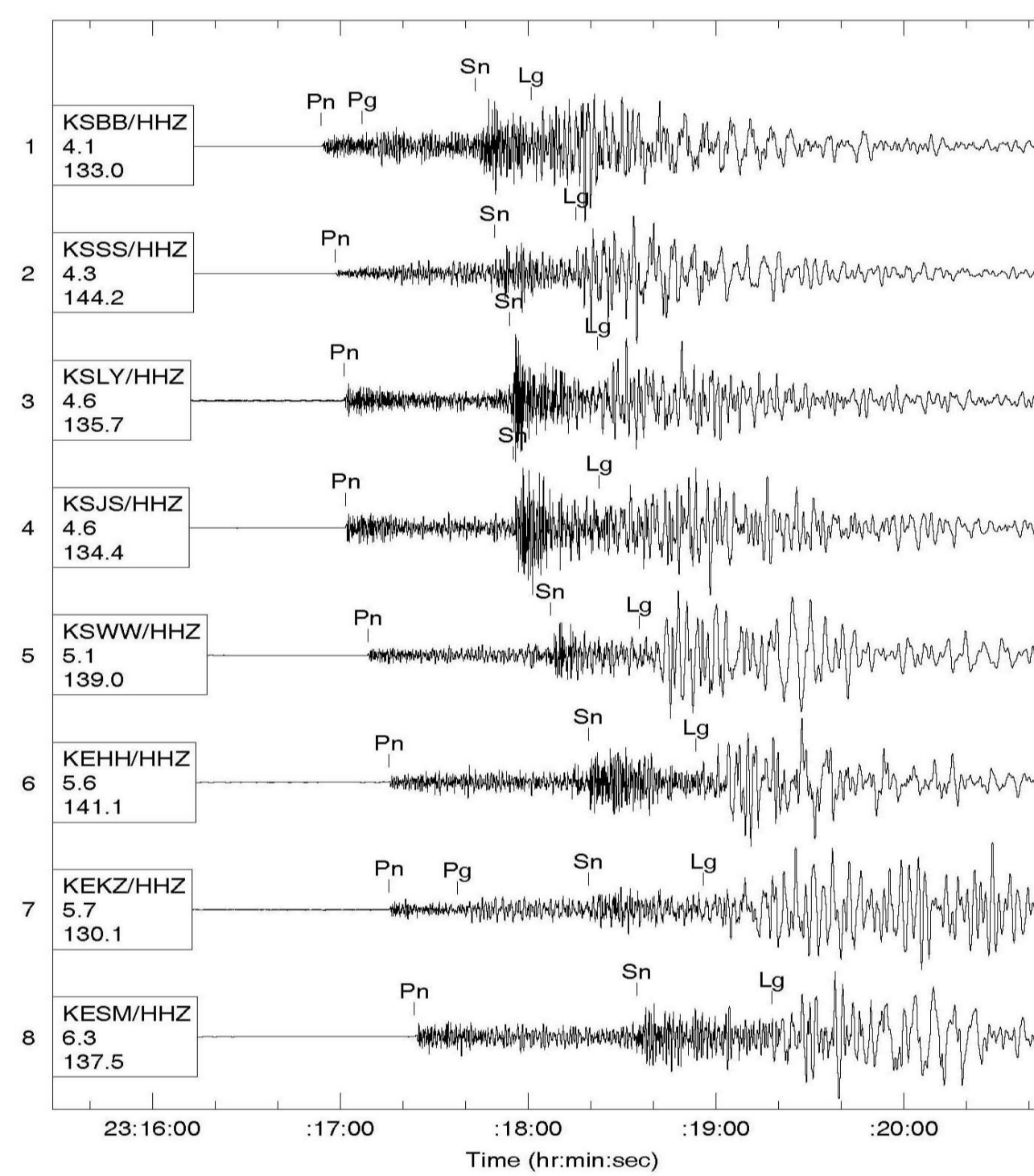


Figure 9. The Hawijah explosion that occurred on 2/6/2015, 21:03:10.7 UT. The local Arabic media reported an airstrike just past midnight 6/3 (+3 hours GMT). The seismic signal is recorded very well by the KSIRS array, and stations SLY and KSSS. The Infrasound signal (7.5 minutes after the *P_g* onset time) is also exceptionally well recorded on the BDF channel, and easily identifiable on the seismic channels of the KSIRS element K101. The estimated duration magnitude of this event is 3.3.

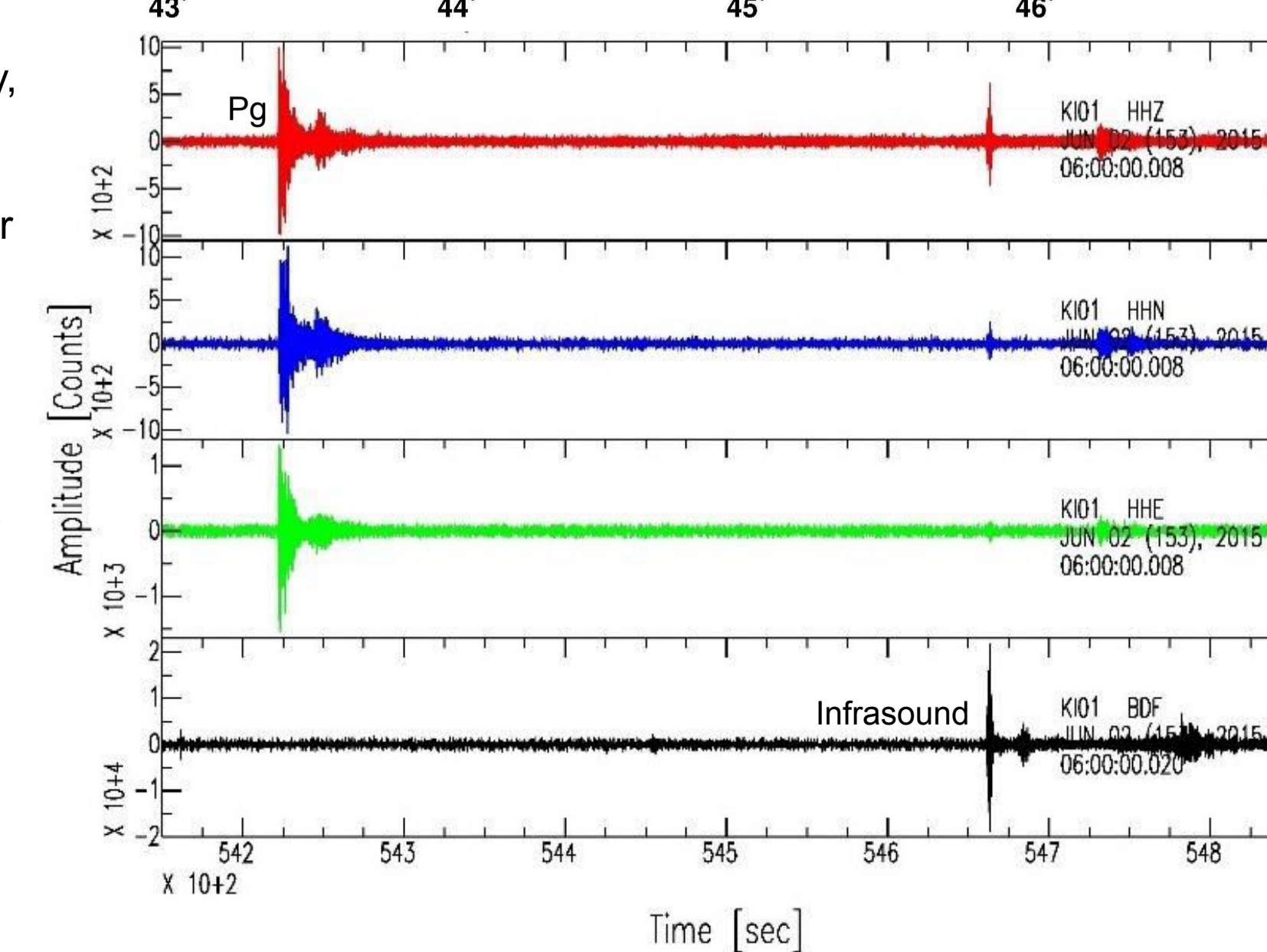


Figure 10. Hands-on and class room training of the host staff.

Summary

- North Iraq Seismographic Network (NISN) (10 stations) established in 2005.
- NISN's circular seismoacoustic array KSIRS (5 stations) established in 2008.
- Iraq Seismographic Network (ISN) (6 stations) reestablished in 2009.
- All stations are 3-component and broadband.
- Most stations equipped with radio, Internet or satellite telemetry; the reset being upgraded.
- Observatories in the cities of Sulaimaniyah (SSO), Erbil (ESO) and Baghdad (BSO).
- So far, over 12000 (updated daily) seismic events located in Iraq and the Middle East.
- Unprecedented database of digital waveforms supporting seismological, environmental and engineering education and research.