The very first marine MT survey in China was completed in summer 2004 with Phoenix on-shore MT equipment adapted for off-shore use.

Zhejiang Petroleum Exploration (ZPX) of Hangzhou, PRC, adapted their existing Phoenix System 2000 to conduct an extremely cost-effective shallow marine MT survey of the oil and gas producing Gulf of Bohai in northeast China. Several Chinese and multinational oil companies are exploring the area.

Marine MT was used because some costly offshore wells in Bohai (based on seismic images of the deep structure) were dry holes; feasibility studies (see p. 2) showed that MT could image the deep structure better than seismic. ZPX found that marine MT cost less than marine seismic, provided better resolution for this problem, and provided faster interpretation turnaround.

Since 1995, marine MT (originally developed by oceanographers for mid-ocean deep crust studies) has been tested and successfully adapted for deep-water oil and gas exploration. Dr. Steve Constable at Scripps Institute of Oceanography in San Diego, California, played a key role in the adaptation of oceanographic marine MT to hydrocarbon exploration.

The initial deep-water (1,000–2,000 m) marine MT tests in the Gulf of Mexico were supported by multinational oil companies, whose use of marine MT is rapidly increasing.

Deep-water marine MT equipment is complex and costly, requiring large vessels and attendant high costs. A single deep-water marine MT sounding point costs about US $10,000 and takes several days to acquire.

However, there are very large shallow-water hydrocarbon prospective areas on the continental shelves and in inland seas (such as the northern Caspian Sea and much of the Gulf of Bohai) where costly deep-water MT equipment is either not required or cannot be used.

ZPX’s first survey comprised approximately 50 MT sites, from 50-100 km offshore, in water about 20 m deep. Electrodes were placed on the sea floor. Magnetic field was measured onshore, and combined with the offshore electric field measurements. Data quality was good, and ZPX has completed 150 sites, both in Bohai and in a new area, the South China Sea, in water up to 50 m deep. ZPX expects the shallow marine MT market to grow.

China plans to spend US$6 billion in Bohai to build 50 offshore oil platforms and drill 1,100 wells. Chinese oil experts believe Bohai could produce 600,000 barrels per day.

continued on page 2

Above: The Chinese fishing trawler that served as the ZPX’s “mother ship”; survey equipment was deployed from a small motor boat. Below: The ZPX crew prepares MT survey equipment on the trawler’s deck. The banner reads, Zhejiang Petroleum Exploration Survey Team 713.

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China Yangtze University (CYU) — MT Feasibility Study in Bohai

Experience shows that seismic images of Bohai’s deep structure may not be reliable. Figure 1 shows a large 70 sq. km. antiformal structure with 200 m of relief, an excellent drilling target determined from seismic. The first well drilled (blue circle) found commercial oil at 5,000 m, but stepout wells drilled only a few hundred meters away were dry. The oil company concluded that the seismic image was not correct.

The oil company then contracted CYU to test MT’s ability to define the deep structure and the target horizon, an ancient, permeable, weathered limestone paleosurface more than 5,000 m below the sea floor. This layer is a good MT target because it has much lower resistivity than either the layered younger sediments above or the basement rocks below.

The MT feasibility study included a line orthogonal to the coast (Figure 2) that was extended into the transition zone during low tide.

The MT and seismic images are shown in Figure 2. The lines are approx. 30 km long; inland is to the right, and seaward, to the left. The resistive basement (orange, red, yellow) dips steeply towards the sea. The target horizon is the conductive band just above the resistive basement. The MT image is clear and continuous. The seismic image (the lower part) lacks definition of the deep structure.

The geological interpretation derived from MT is shown in Figure 3. The basement is faulted into horst-and-graben blocks. The well in Figure 1 was drilled to the horst block on the left in Figure 3. CYU’s onshore / transition zone MT work showed MT could be used to map deep target horizons in Bohai, and that MT is an economic and useful complement to seismic.

Professor Wenbao Hu of CYU participated in the Bohai feasibility study.

Figure 1

Figure 2: Comparison of 2D Inverted MT Resistivity Section (top) with Seismic Section (bottom)

Figure 3: Geological Interpretation Based on MT Profile
Studies in 2003 and 2004 in Alberta, Canada, and in Japan show that “broadband” MTU-5A equipment (with MTC-50 induction sensors) can acquire long-period data equivalent to a specialized long-period system with a fluxgate magnetic sensor.

**23 Day comparison (MTU vs. fluxgate) Oct-Nov, 2004**

The experiment was conducted mainly by the University of Alberta at their long-period test site. Fluxgate-system data processing was done by the university.

Two separate Phoenix systems were used (900m apart), together with one fluxgate system. The second Phoenix system permitted the parallel sensor noise test (shown below). Results of this experiment are summarized in the plots described below.

Figure A shows the transfer functions for fluxgate system (left hand side) and those of the MTU-5A / MTC-50 induction sensor system (right hand side.)

The spectra are very similar within the overlapping bandwidth, although the fluxgate system shows somewhat higher phases at the longest periods. The Phoenix system plots 1 frequencies per decade.

Figure B (upper) shows the S/N ratio spectra of the induction sensors across the whole available bandwidth, using the well-known parallel sensor noise test procedure. The moderate noise at the highest frequencies was due to maintenance visits of the field truck a relevant operator motions and could be easily eliminated using slightly different layout configuration and maintenance procedure. The noise floor of the sensors remains below the signal amplitude even at the lowest frequencies. In Figure B (lower) the coherency remains close to 1 except at the highest periods – again due to the above-mentioned maintenance visits.

**Background:** Long-period MT (2,000 sec to 100,000 sec) is used for deep crustal studies such as diamond exploration (see Issue 15). Most long-period systems use a “fluxgate” magnetic sensor because fluxgate low-frequency performance was thought to be superior to that of induction sensors.
19 Day Study: Sawauchi Monitoring Station in Japan

Phoenix operates a 24/7/365 fully automated, solar-powered, internet-linked MTU-5 monitoring site at Sawauchi, Honshu, Japan (see Issue 31). The plot below shows the results of processing 19 days of continuous Sawauchi data.

The magnetic amplitude spectra extend smoothly and continuously to approx. 100,000 seconds.

**Magnetic Amplitude Spectra:** 19 Days Continuous Recording, Sept - Oct. 2004

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**Summary**

- The normal wideband induction sensor provides long-period magnetic field data equivalent to the specialized fluxgate sensor used in specialized long-period systems.
- Both types of sensor can obtain data to periods of ca. 50,000 seconds or more.
- With either type of sensor, the data are often quite noisy at periods longer than 20,000 sec.
- The long-period scatter is not due to electrode instability, since Phoenix long-period electrodes were proven to be extremely stable by Japanese scientists in 1999.

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May, 2003 5.7 Day Comparison study by University of Alberta, Canada

Prof. Martyn Unsworth and Dr. Wolfgang Soyer of the University of Alberta, Edmonton, compared fluxgate vs. induction sensor in a 5.7 day side-by-side test of Phoenix equipment vs. the Geological Survey of Canada’s Long Period MT System (LIMS). Results are shown in the plots below.

Dr. Soyer concluded that: (1) the integrated dB/dt time series from the induction sensors agrees well with the magnetic field time series from the fluxgate sensor (2) the transfer functions from the two different systems are equivalent.

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**Ministik Lake (Elk Farm): 5.7 Days of simultaneous side-by-side recording, May 2003**

**Phoenix MTU5A: 2 Boxes: 2E + 2H**

Phoenix electrodes & MTC-50 induction coils

5.7 Days of Acquisition, May 2003

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**GSC-LiMS**

Phoenix electrodes with Fluxgate magnetometer
NEWS FROM AROUND THE WORLD

CANADA

Phoenix conducted a survey in Rainy River, Ontario, for Nuinsco in November.

**Right:** Billy Faragher, Oleks Hlazyrin, and Mitchell Lackie

IRELAND/INDIA

Dr. Alan Jones of DIAS (Dublin) and Dr. Rao of IIG (Mumbai) are both expanding their systems. Dr. Rao is a visiting scientist at DIAS.

RUSSIA

Nordwest Co. of Moscow was extremely active in 2004, measuring almost 3,500 MT sites. Nordwest worked all over Russia; international work included a job in Armenia and a 600-site 3D MT survey in Bulgaria.

**Right:** Nordwest’s Phoenix equipment at Mutnovskaya geothermal power plant on the Kamchatka Peninsula in the Russian Far East.

**Below:** Nordwest used horses for access to MT survey sites in Chukotka, a remote region in Arctic Siberia.

CHINA

Clients in China have now ordered ten V8 systems with various functions. Deliveries have been made to BGP-5th Division, Xinjiang Geology and Geochemistry, and Beijing Geoscience University.

LIBYA

BGP International in Tripoli, Libya, rented ten MTU-5A systems for a 400-site 3D MT survey for an oil company client in central Libya during summer 2004. Here the field crew prepares to calibrate the equipment in the Libyan desert.

USA

Montason (USA) is developing new EM techniques for oil and gas exploration. See [www.montason.com](http://www.montason.com) for details.

**Right:** Montason President Vic Grabian in Phoenix booth, SEG in October

**Above:** Montason field crew with Phoenix truck-mounted T-30 transmitter and MG-30 motor generator

RUSSIA (continued): SPMI completed more large-scale MT surveys in Russia in 2004. Below, an SPMI crew works near an oil drilling rig. Temperatures were as low as -55°C.
ON THE ROAD

USA: Carlos Guerrero, Yann Avram and Leo Fox represented Phoenix at the 74th Annual Meeting of SEG in Denver, Colorado, October 10-15. New SEG president Craig Beasley, left and outgoing president Peter Duncan, right.

India: Phoenix president Leo Fox attended the 17th Electromagnetic Induction Workshop held at the National Geophysical Research Institute (NGRI) in Hyderabad, India, Oct. 18-23. The workshop is the premier venue for EM researchers to exchange research results and new developments. Special thanks to Dr. Harinarayana (head of the local organizing committee) and to Prof. Baldev Arora.

Above: opening ceremony with George Jiracek, (USA member of the working group), left, and His Excellency, Shri Surjit Singh Barnala, centre, Governor of the state of Andhra Pradesh.

Japan: Leo Fox and Mits Yamashita attended the SEGJ, in Sendai, Japan, November 2004.

MESSAGE FROM THE PRESIDENT

Phoenix will be 30 years old in May, 2005. Although many geophysical companies have disappeared in recent years, Phoenix is thriving, growing and developing new products such as the V8 wireless data acquisition system. Visit our booth at the PDAC in Toronto (March, 2005) for details about our 30th birthday party!

The October 2004 issue of The Phoenix marked the 10th year of its publication. We started in black and white in 1994, moving to full color in 2003. We've stopped wondering what to write about and now worry how to find space for all the news and pictures.

Feedback from our readers around the world is gratifying. Thank you to all who have submitted great photographs, information from their surveys and story ideas. Please keep them coming.

~Leo Fox