Heading title: Patras Gulf pockmark field

GEOPHYSICAL - GEOCHEMICAL INVESTIGATION AND LONG-TERM MONITORING OF THE ACTIVE POCKMARK FIELD OF PATRAS GULF, GREECE

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INTRODUCTION

An intergraded marine geophysical and geochemical survey was conducted in the active submarine pockmark field of Patras Gulf, in the framework of BLUEL project. BLUEL focused on the detailed mapping of the field (partially now covered by the Patras harbor installations) and the investigation of the source and the composition of the released gas, the possible links of the gas flows and the local seismicity and the interaction between gas releases and surround seafloor. The field has been formed in shallow waters and in the past had presented intense activity linked with earthquakes shakes (5.4 and 6.4 R on July 14th, 1993 and June 8th, 2008) causing among others, changes in bottom water temperatures due to gas seepage. In order to investigate the complex relationship between gas seepages and seismicity, seafloor temperature data was acquired for a period of more than 1.5 years, using a 200 m long Distributed Temperature Sensor (DTS) system.

1. METHODOLOGY

Initially, a high resolution marine geophysical surveying conducted in the pockmark field aiming to map in detail the changes of seafloor morphology and shallow stratigraphy relative to gas seepages and to investigate the local faulting. The surveying utilized modern technology consisting of: (i) a multibeam echosounder, (ii) a high resolution sub-bottom profiler (Chirp type), (iii) a dual frequency side-scan sonar and (iv) a ROV (Remote Operated Vehicle) for the optical confirmation of sites of interest. Ground water and gas samples were collected from a well on the shore next to the pockmark field. All samples were analyzed for C1-C6 hydrocarbons, He, H2, Ar, O2, CO2, N2, using a Carle AGC 100-400 TCD-FID GC 215 with accuracy and precision 2 % (1σ)) and isotopic compositions d13CCH4, d13CC2H6, 216 d13CC3H8, d2HCH4, using Finnigan Delta Plus XL mass spectrometer with precision ± 0.3 217 ‰ (1σ) for 13C, ± 4 ‰ (1σ) for 2H). The SILIXA Ultima-Distributed Temperature Sensor (DTS) system was installed, known for its fanless design for improved reliability, its increased data storage capacity, and its low energy consumption. The system excels in maintaining precise temperature and sampling accuracy, achieving resolutions of 0.01°C and 25cm, respectively. A specific pockmark, located at the shallowest part of a pockmark string aligned with an active fault, inside the Patras harbor, was selected for the deployment of the DTS. In the acquired DTS data sets a combination of statistical methods were applied. These included the application of CLEAN algorithm for filling missing data and the

Inverse Discrete Fourier Transform (IDFT) for the reconstruction the time series. Spectral and time series analysis applied in the processed data. Meteorological parameters and sea level height measurements were obtained from weather and tide stations. Employed environmental parameters eventually contained wind speed and direction, precipitation height, atmospheric temperature, and sea level height, all sampled in a 1-min interval for the studied period. The microseismic monitoring of the area accomplished with the deployment of in total six (6) new seismic stations which together with the existing ones (National Seismograph Network) developed an effective seismic network. The processed data sets retrieved from the operation of the DTS system, the meteorological and environmental data as well as the data from microseismicity monitoring were correlated and synthesized.

2. RESULTS

The marine geophysical survey provided new deep insight into the Patras Gulf pockmark field. The surveying significantly increased the number of the pockmarks to 115 from 72 known from previous surveys (Fig. 1). The field covers a well-delimited area of 2.4 km^2 between the 17- and 45-meter isobaths. The results showed that the main mechanisms for the development of the field are the local tectonism and the internal characteristics of the sedimentary layers as gas-charged related acoustic characters (acoustic turbid zones, enhanced reflectors, gas pockets, columnar disturbances, gas plumes) were detected [Christodoulou et al. 2023]. These mechanisms appeared also as major contributors for the spatial distribution and the morpho-geometric patterns of the pockmarks during the stages of the field growth. The morphological characteristics of the pockmarks suggest recent activation and the presence of gas recorded in the acoustic data sets acquired from the sedimentary deposits below the seafloor as well as the water column (gas flares) [Christodoulou et al. 2023]. Isotopic analysis that was applied in water samples regarding their composition in C1, C2, C2H4, C3, iC4, nC4, iC5, nC5, C6+, He, H2, Ar, O2, CO2, N2, CO, H2S και δ13C1, δDC1, showed that CH4 of microbial origin is the dominant component of the released gas. Although data sets of large number of seismic events were recorded during the monitoring period (1.5 yr), no significant local earthquakes occurred during that period and the relation between seismicity and irregular seabed water temperature events was not systematic. The DTS data processing showed that four (4) thermal events appear to have a causative link with the local seismicity [Fakiris et al. 2023] presenting a possible relationship with swarms of low to moderate-magnitude local earthquakes. Three of them show a remarkably similar pattern: a 4 °C temperature increase with a duration of 4–5 days each, with their peaks almost synchronous to the seismic events [Fakiris et al. 2023].

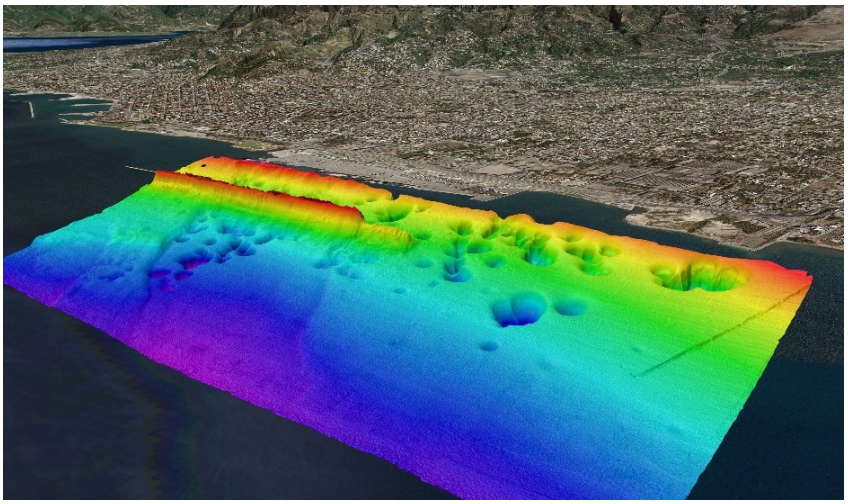

Fig. 1. Bathymetric map of the Patras Gulf pockmark field.

3. CONCLUSIONS

A multidisciplinary survey consisting of high-resolution geophysical means and geochemical analyses provides new insights to the Patras Gulf pockmarks field. This survey has not only revealed the existence of new pockmarks, but it has brought new knowledge regarding their spatial distribution and the level of activity, their link with the structural framework of the area, the fluid escape structures, and the fluid pathways used, and finally the origin of the fluids. The operation of a DTS, as a low-cost long-term monitoring system, proved as a promising approach towards the examination of the causative relationship between local seismicity and gas seepages from an active pockmark field.

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