

Remotely Sensed Data Application for Hydrocarbon Exploration Offshore Ukraine*

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Abstract

This study features the research program developed at *CASRE* to apply space-born data to oil and gas prospecting in the Black Sea Basin. The program includes processing and thematic interpretation of space-born imagery coupled with analysis of available geological, geophysical, hydrophysical, environmental and meteorological information. The applied technique is based on rather simple and clear theory, and the prognostic power of which is proved by experiments, numerical modeling and exploration practice. It is based on immanent attribute of oily material to attenuate higher harmonics of sea waves due to surface tension forces of the film at the water-air interface (Marangoni effect). That is why a microwave radar signal beamed from orbit onto a smoothed sea surface backscatters to the sensor with a low impedance that drastically, up to 20 *dB*, differs from surrounding wavy medium if the wind velocity ranges from 3 to 10 *m/s*. Oil slicks form very characteristic features and patterns on the sea surface and produce peculiar semi-lunar, dogleg, spiral, snake-like and star-like patterns.

The repetitive oil slicks in two areas, west and south of Tarkhankut Peninsula and south of Cape Opuk of Crimea (known for numerous submarine gas seeps, mud cones and pockmarks) allowed delineation of hydrocarbon emission zones and selection of first-order prospects to increase success ratio within this highly promising but still immature hydrocarbon-prone basin. A comprehensive analysis of all available data permitted to conclude (2004) that an optimal solution is to spud the first wildcat within the Subbotin prospect where rather thick Plio-Quaternary seal rocks cap the eroded crest of the Maykop Anticline.

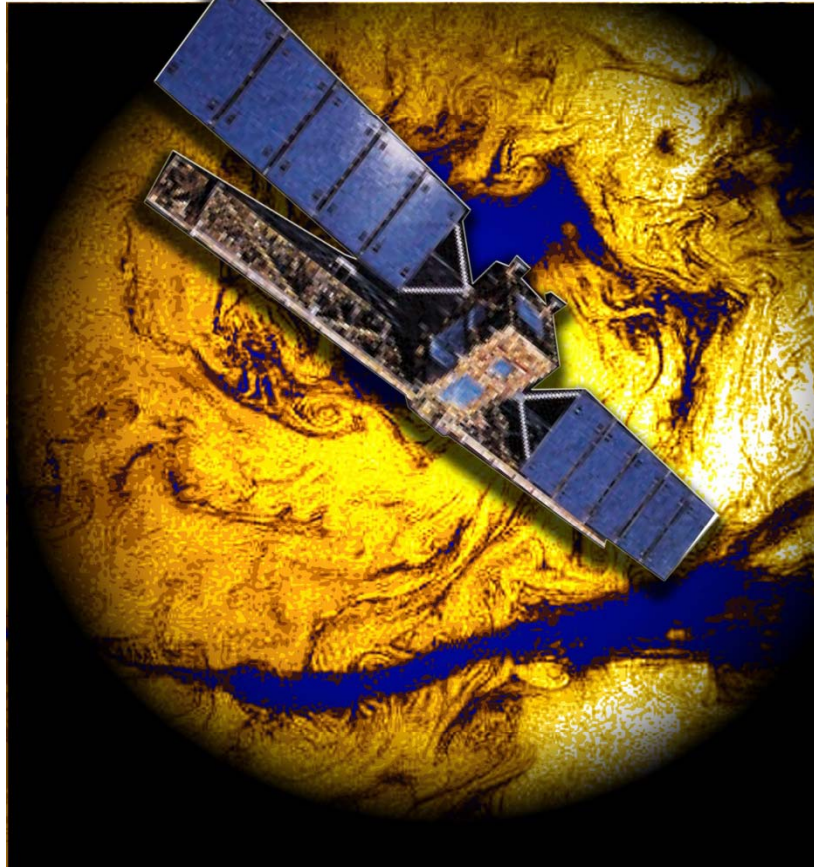
As to the NW shelf, the data appear complicated due to significant pollution coming from the Danube and Dnieper, accidental spills along main tanker routes and ship lanes, leaks from exploration platforms and intensive algal bloom during summer months. Several slick groups of higher population density were recorded nearby Zmeiny Island on the western part of the area studied; however, they

were deselected from consideration for the moment due to an ambiguity caused by severe pollution of the sea with oil products. Nevertheless, it was possible to discriminate natural oil manifestations from spills and confidently delineate several emission zones, and one of them to mention is the Pribiyna prospect located west of Tarkhankut Peninsula, near Krymske Gas Field. The radar images of this area demonstrate a compact group of slicks (5 repetitions) shown on *ERS* scenes. It is worth mentioning that Pribiyna prospect is located not far from the onshore West Oktyabrske Oil Field. There is some evidence that certain phenomena like earthquakes, solid Earth tides and strong barometric fronts affect submarine seepage activity and produce higher slick population density, however, these assumptions need to be proven with proper statistic retrieval of the data.

Alexander Kitchka

**Centre for Aerospace Research of the Earth
IGS NASU**

UKRAINE'S OFFSHORE • RADAR SURVEY



***Remotely Sensed
Data Application
for Hydrocarbon
Exploration
Offshore Ukraine***

*AAPG European Region
Conference,
Kiev, 18 October 2010*



An epigraph: Marangoni's phenomenon



Jules Verne

JULES VERNE.

Dick had the forethought also to order about a dozen barrels of their cargo to be brought in front, so that when the "Pilgrim" struck, the oil escaping and floating on the waves would temporarily lull their fury, and make smoother water for the passage of the ship.

Now, my lads!" he cried to his crew, "now's your time; out with your oil! Let it run!"

Ready for the order, the negroes poured out the oil, and the raging waters were stilled as if by magic. A few moments more and perchance they would rage more vehemently than ever. But for the instant they were lulled.

The "Pilgrim," meanwhile, had glided onwards, and made dead for the adjacent shore.

Jules Verne

"Un capitaine de quinze ans"

1878

Assessment of oil pollution

Oil pollution of the Black Sea

Source of Pollution	Bulgaria (t/y)	Georgia (t/y)	Romania (t/y)	Russia (t/y)	Turkey (t/y)	Ukraine (t/y)	Total (t/y)
Domestic	5,649.00		3,144.10		7.30	21,215.90	30,016.30
Industrial	2.72	78.00	4,052.50	52.78	752.86	10,441.00	15,379.86
Land-Based				4,200.00		5,169.20	9,369.20
Rivers	1000.00			165.70		1,473.00	2,638.70
Total	6,651.72	78.00	7,196.60	4,418.48	760.16	38,299.10	57,404.06

**Total from the Black Sea
Coastal Countries** 57,404 t/y

Accidental Oil Spills* 136 t/y

From the Danube River 53,300 t/y

**TOTAL IN THE BLACK
SEA** 110,840 t/y

Note: * The value of accidental oil spill is average for the last years.
 There is not included any information for illegal discharges from shipping.

Sources of the information:

1. National Reports "Assessment of Land-Based Sources of Pollution", 1996.
2. First Meeting of the Emergency Response Activity Centre, Varna, May 1994.
3. <http://www.grid.unep.ch/bsein/tda/files/3a18t.htm>

The Problem

■ *Kovalev S.K., Kubrianov A.I., Demyshev S.G. , 2004. Parameterization of chemical and biological processes and numerical modeling of petroleum hydrocarbons seasonal change in aerobic zone of the Black Sea. Marine Hydrophysical Journal, no. 1, pp. 26-39. (in Russian)*

ONE OF THE CONCLUSIONS:

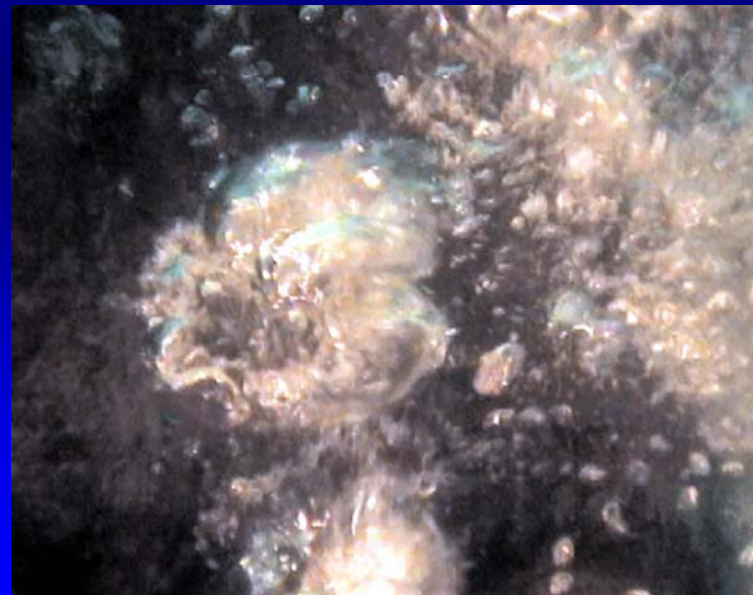
Annual oil pollution of 110-130 Kt/y is close to ultimate absorption capacity of the basin. However, ten years of direct observations at sea say that measured concentrations of hydrocarbons in the Black Sea waters are twice as much those predicted by numerical modeling and assessment of net oil pollution made by environmentalists.

Published estimates of oil influx to the basin can be significantly underestimated.



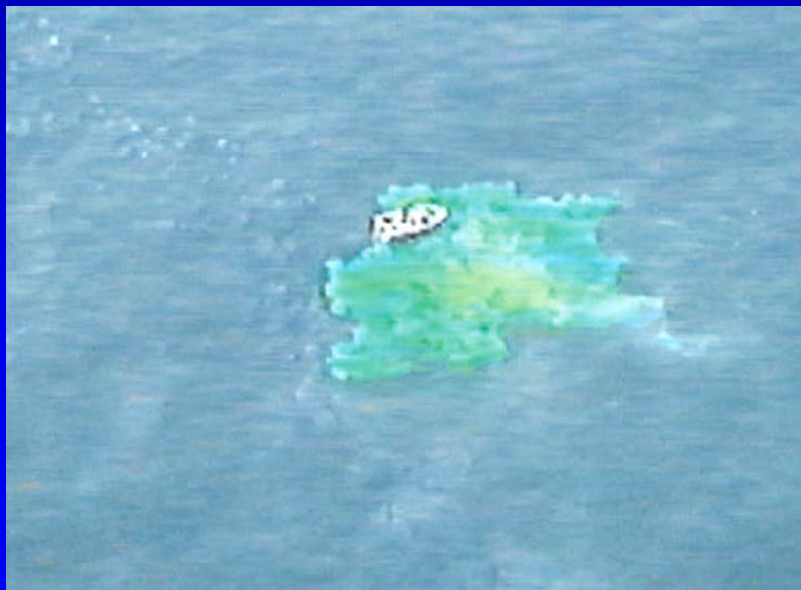
Phenomenon

■ This exploration technique employs a possibility of recognizing on radar scenes the hydrocarbon films that appear on the sea surface owing to upward migration of oil from the deposit in sedimentary traps. Liquid hydrocarbons can come to the water column from submarine sources in the form of oil itself, gas condensate, or as admixture to natural gas transported by gas seeps acting permanently, or much typically, with some periodicity, like submarine geysers.



Bubbleology

■ Gaseous and liquid hydrocarbons always come to the top and can emerge even in two-phase state (water emulsions in oil) and then decay at the sea surface and amalgamate into a single continuous film or several spots of micron thickness



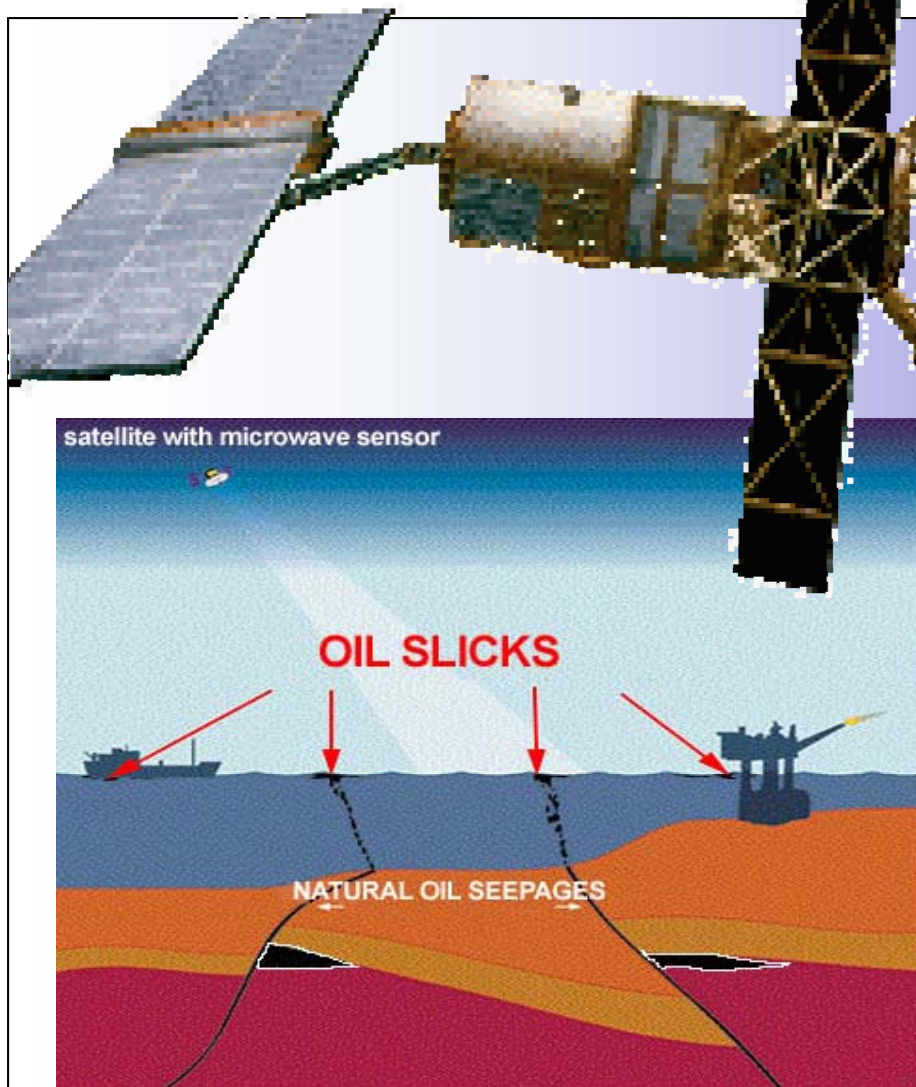
www.bubbleology.com



[NPA Group website](#)

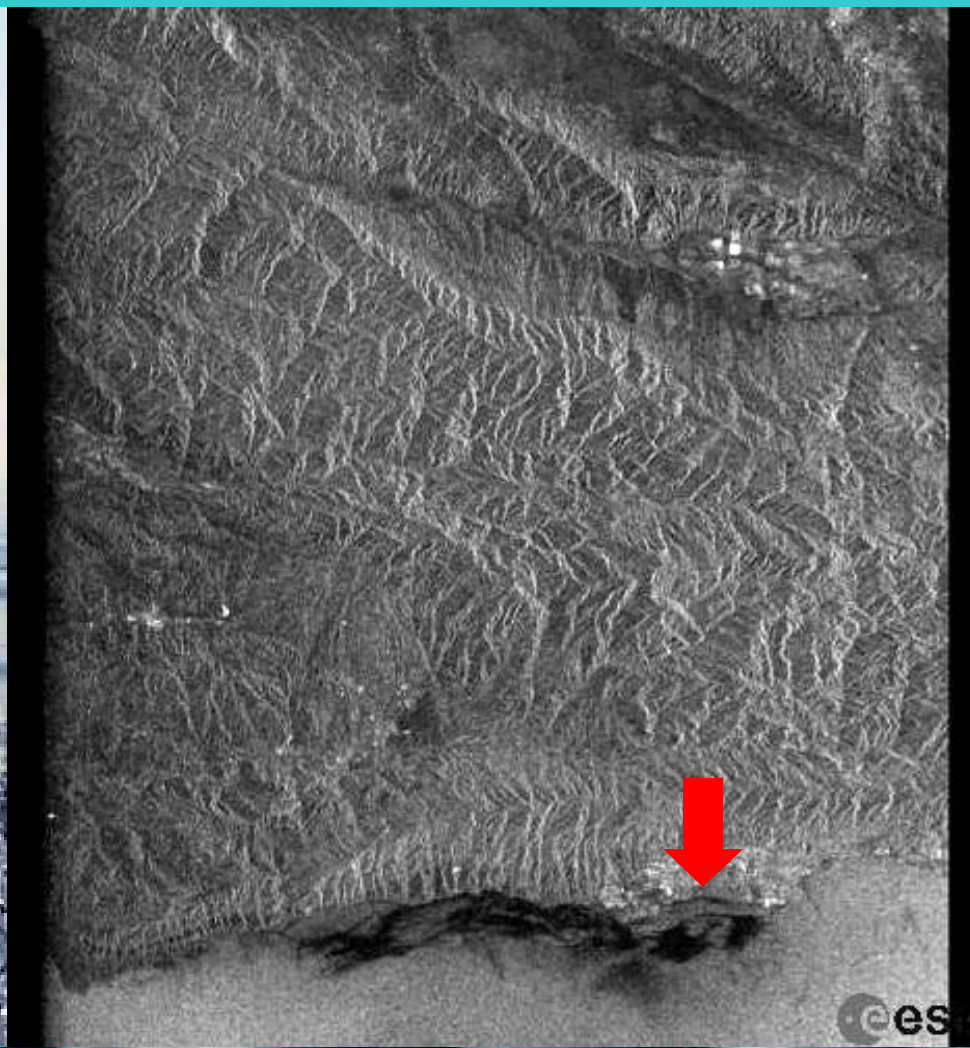
Technique

■ The applied technique is based on immanent ability of oily material to damp higher harmonics of sea waves (so-called capillary ones) due to surface tension forces the film produces. That is why radar signal (of 5.67 cm wavelength for *ERS-1,2*) beamed onto a smoothed air-water interface backscatters to the sensor with lower impedance (visible dark areas) that drastically, up to 20 dB, differs from surrounding wavy medium (visible light-gray background) if wind velocity exceeds 3 m/s.



La Goleta natural oil seep

UCSB Hydrocarbon Seeps Project



Slicks 1

■ Man-made pollution

Ballast waters...

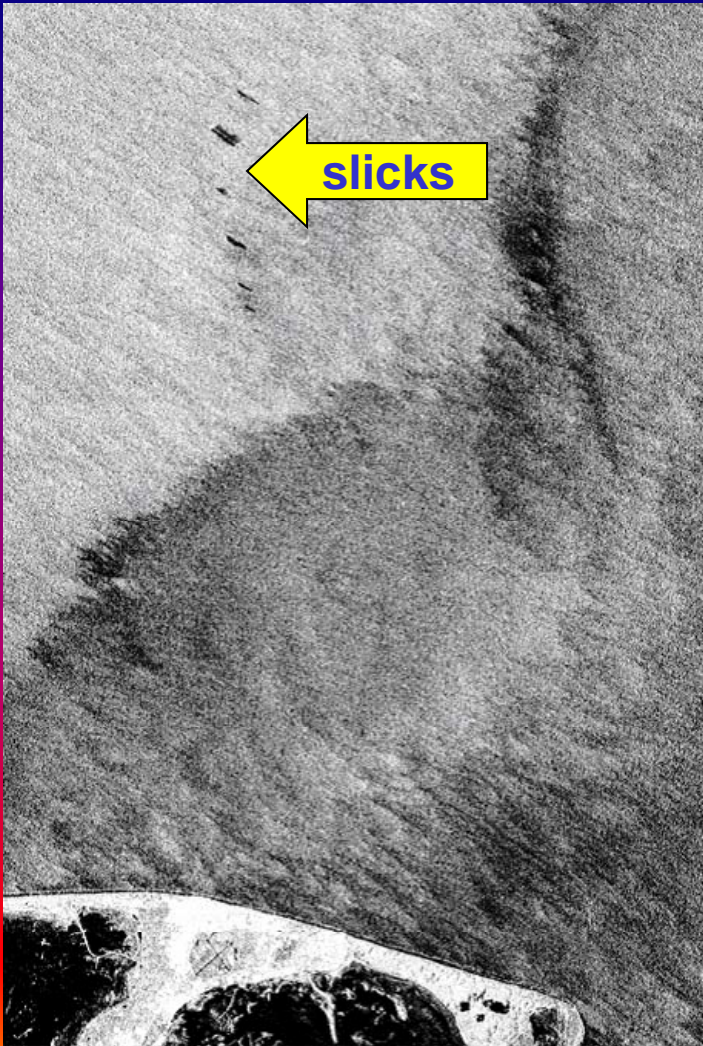
Blowout at Union Oil's Platform A
January 14, 1969



Oil slicks parameters

<i>Type of oil manifestation</i>	<i>Appearance</i>	<i>Approximate thickness</i>	<i>Approx. volume, M^3/M^2</i>
Oil sheen	Silver and mirror-like film	>0.0001 mm	0.1
Oil film	Iridescent film	>0.0003 mm	0.3
Crude oil or fuel	From brown to black	>0.1 mm	100
Emulsion of water in oil	Brown or orange	>1mm	1000


Experiments



■ Radar image of artificial oil slicks

This image was acquired by the Spaceborne Imaging Radar-C and X-band Synthetic Aperture Radar (SIR-C/X-SAR) aboard the space shuttle Endeavour on October 6, 1994, NASA

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 0.50 0.50

From:
 1 Mar 1992

To:
 1 Mar 2004



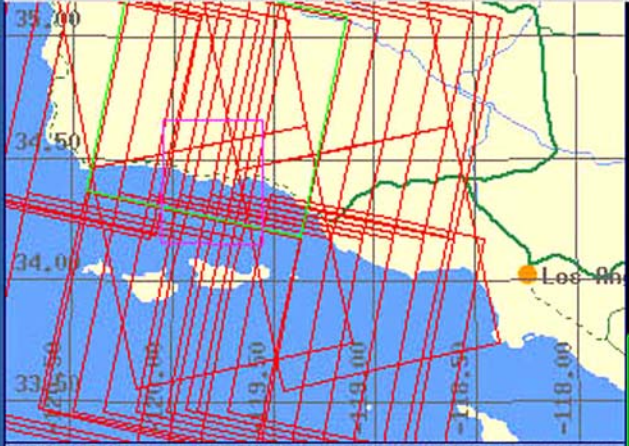
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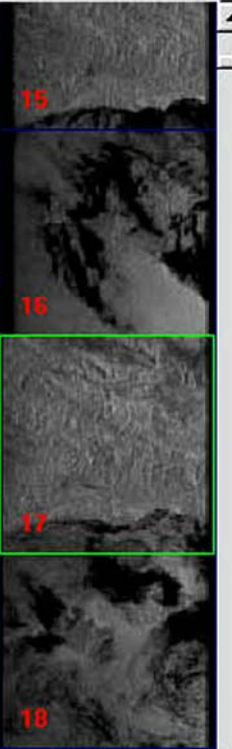
← → 🌐 ⌂

Navigate Set Area Footprints



1 record selected

Id	Product	Mission	Sensor	Start Date	Start
9	RAW	ERS-1	SAR	1992-12-15	18:42:
10	RAW	ERS-1	SAR	1993-02-23	18:42:
11	RAW	ERS-1	SAR	1993-03-30	18:42:
12	RAW	ERS-1	SAR	1993-08-17	18:42:
13	RAW	ERS-1	SAR	1993-10-26	18:42:
14	RAW	ERS-1	SAR	1993-11-30	18:42:
15	RAW	ERS-1	SAR	1992-06-04	18:39:
16	RAW	ERS-1	SAR	1992-06-04	18:40:
17	RAW	ERS-1	SAR	1992-07-09	18:39:



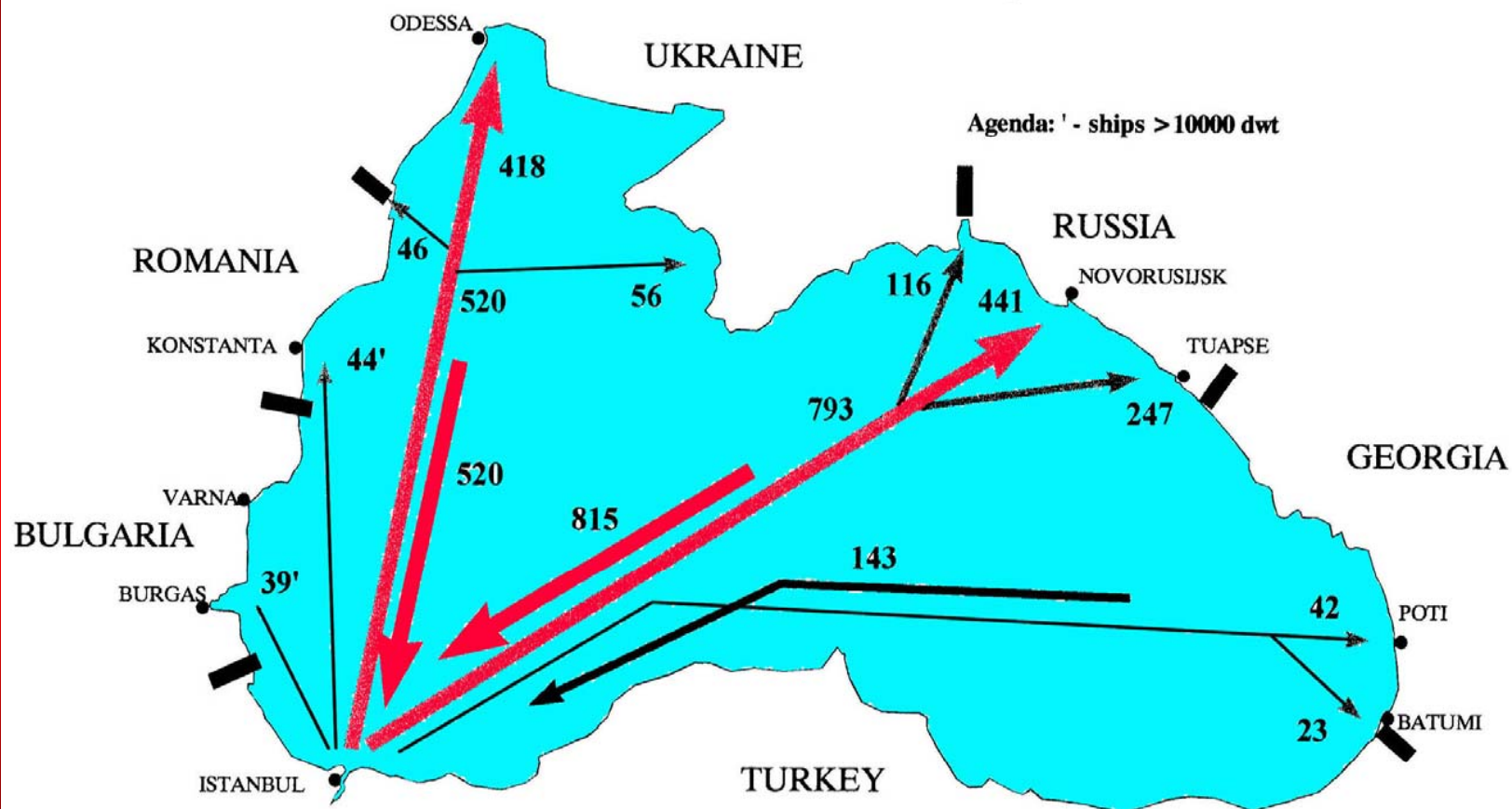
☒ Display

CHALLENGES

- **ERS SAR, ASAR ENVISAT, and other full-resolution radar images are quite expensive data**
- **ERS SAR quick-looks are of lower spatial resolution and cannot be properly georeferenced, corrected, etc.**
- **Discrimination of natural oil slicks from natural films and spillages is rather ambiguous task**
- **Depending on the season local sea currents within the South Kerch offshore vary from ~ 5 to few tens of cm/s**
- **Lack of direct slick observations at sea corresponded to the available images**
- **Only few compositional analyses of submarine seeps in the Black Sea are available to the date**
- **There are some submarine waste disposal sites offshore South Kerch Peninsula**

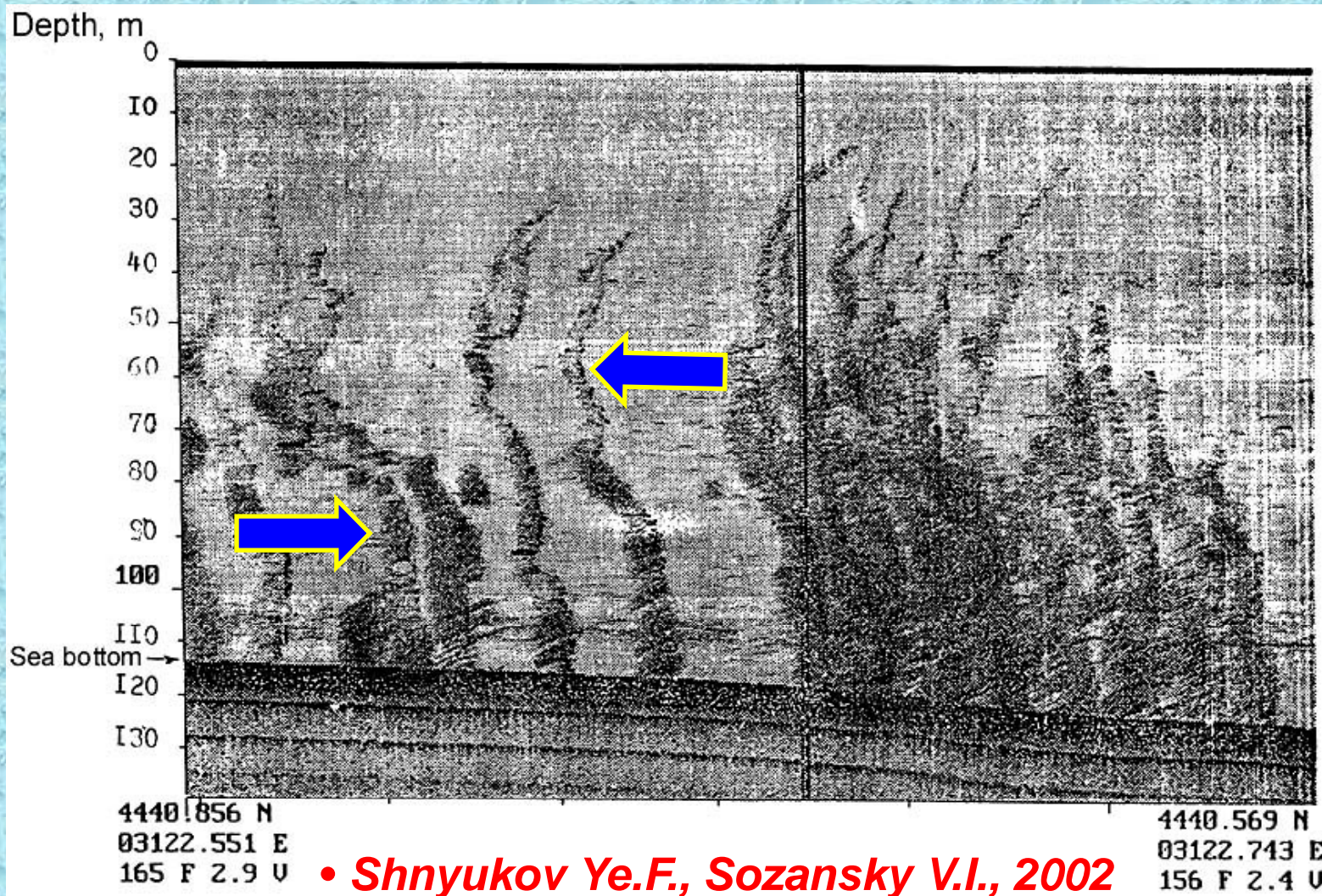
Tanker routes

1995: Main Tanker Movement via the Bosphorus

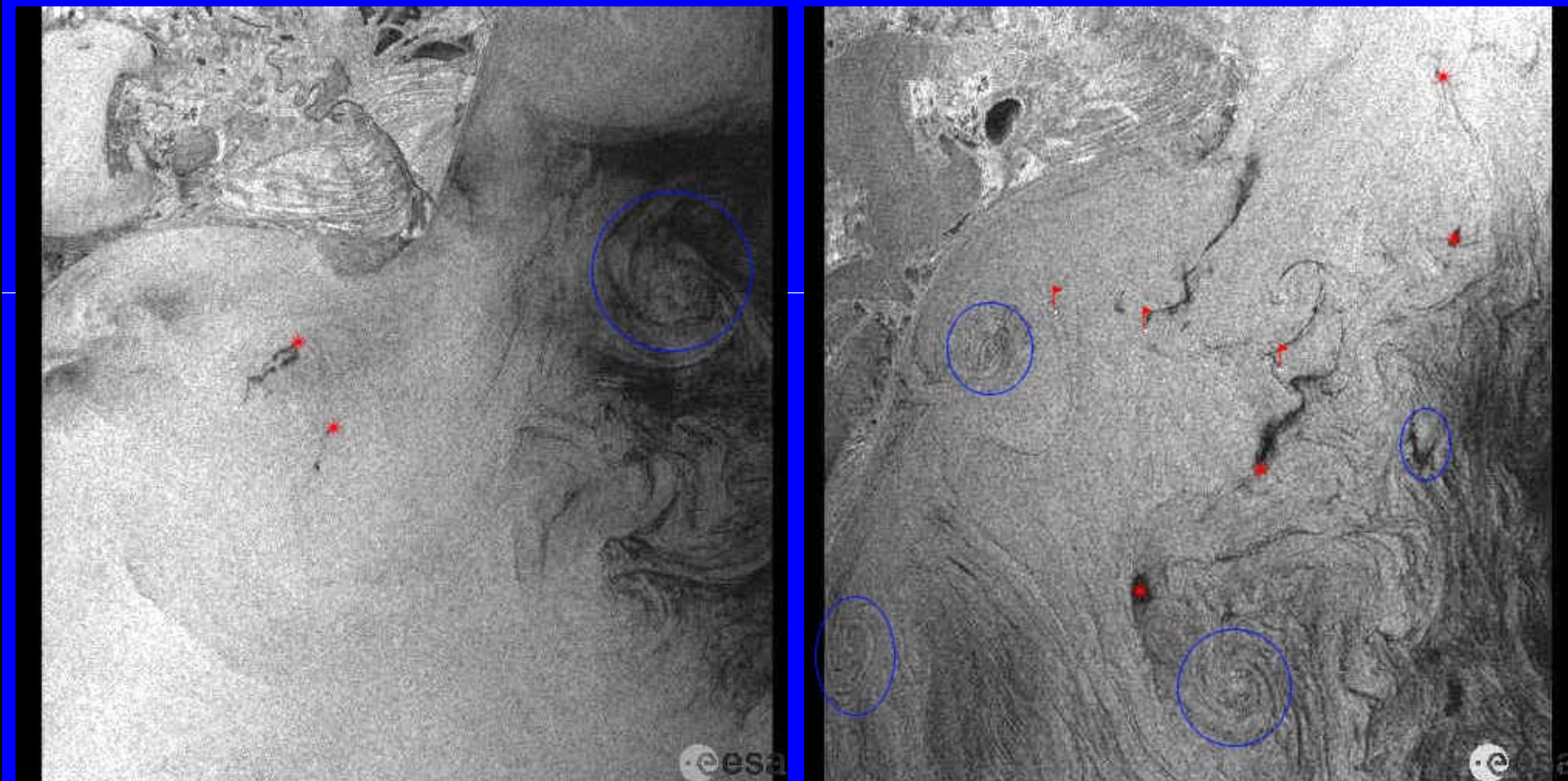


Stoyanov L.A. and Balashov G.D., 1998

Seep trajectories vs. sea currents

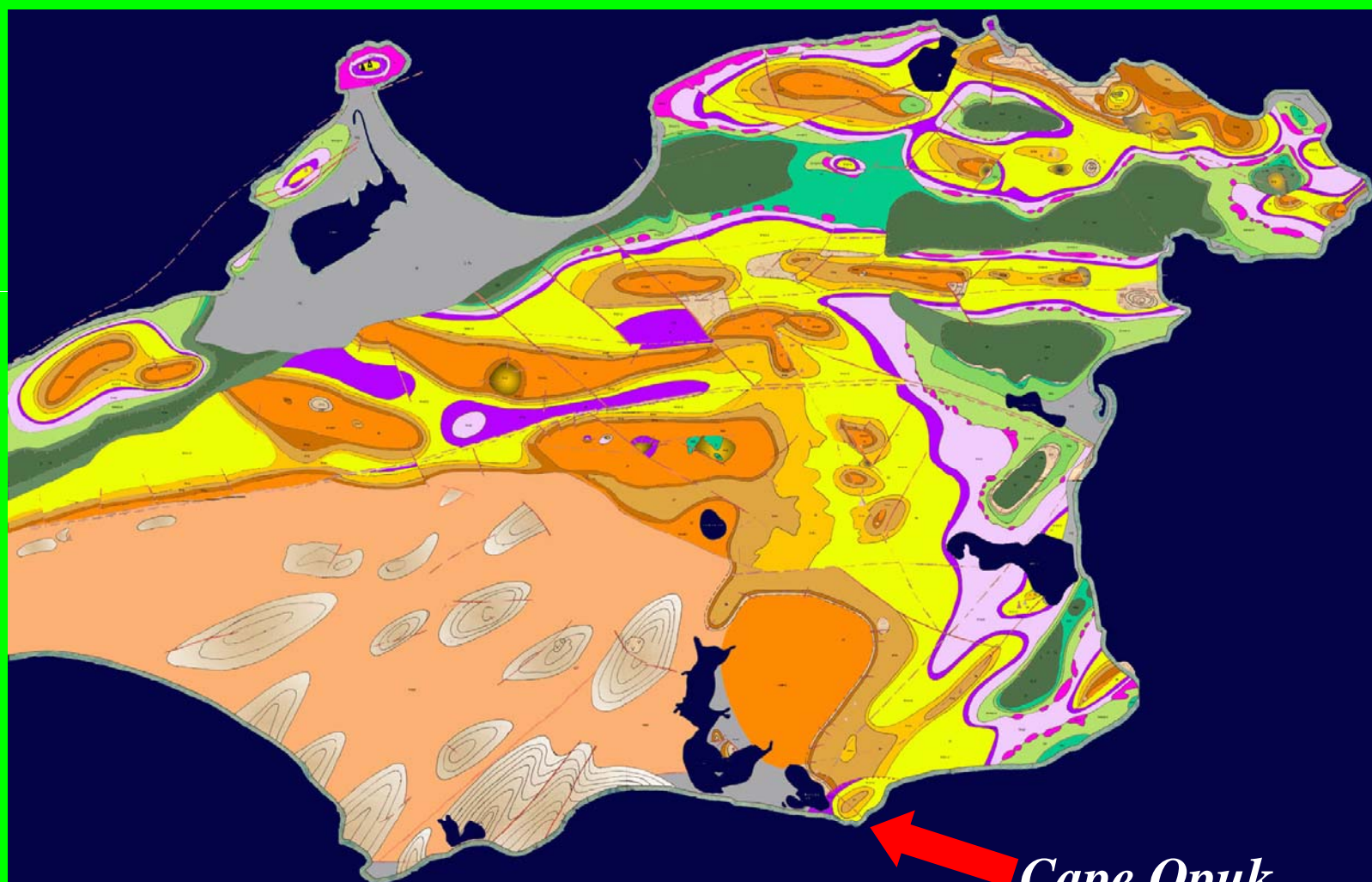


Romanian offshore



■ *Lebada and other fields on ERS-SAR scenes*

Geological map



■ **Kerch Peninsula, Scale 1: 100000**

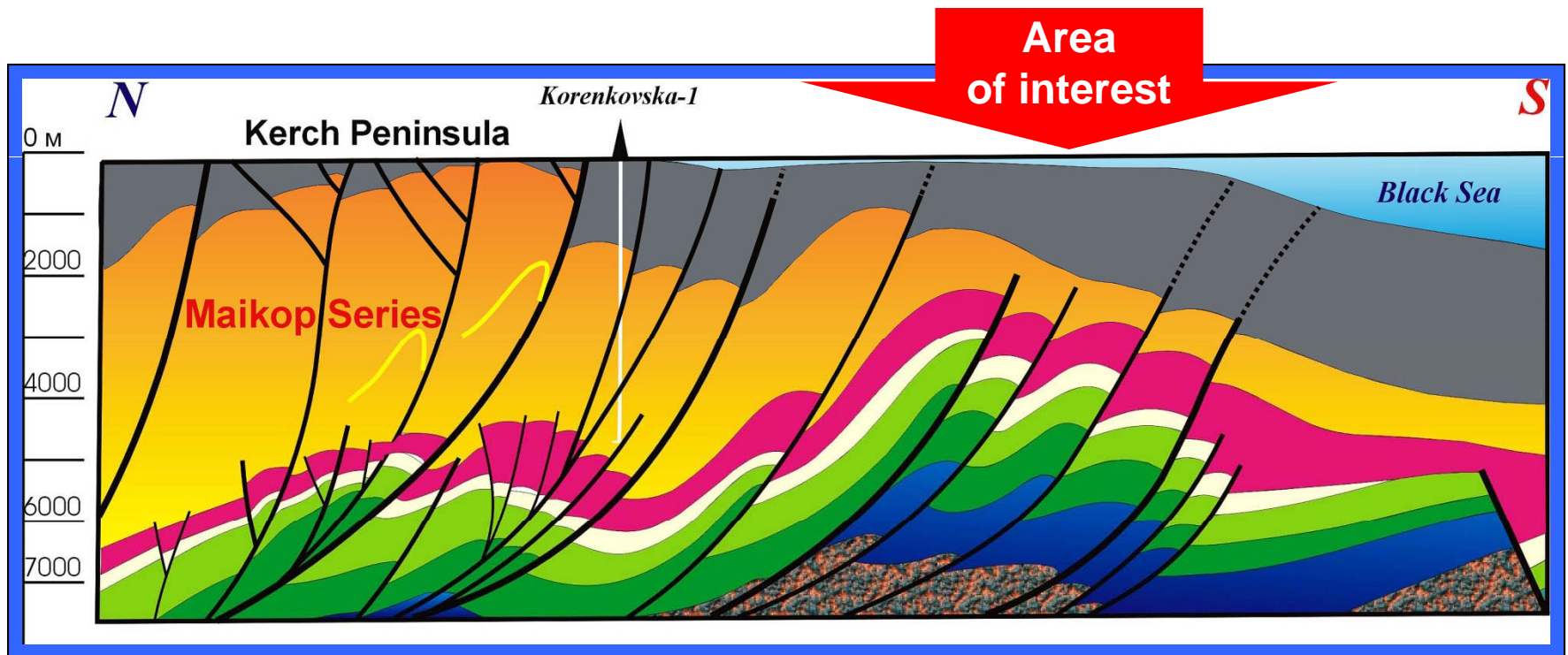
Cape Opuk

Miocene limestones outcrop



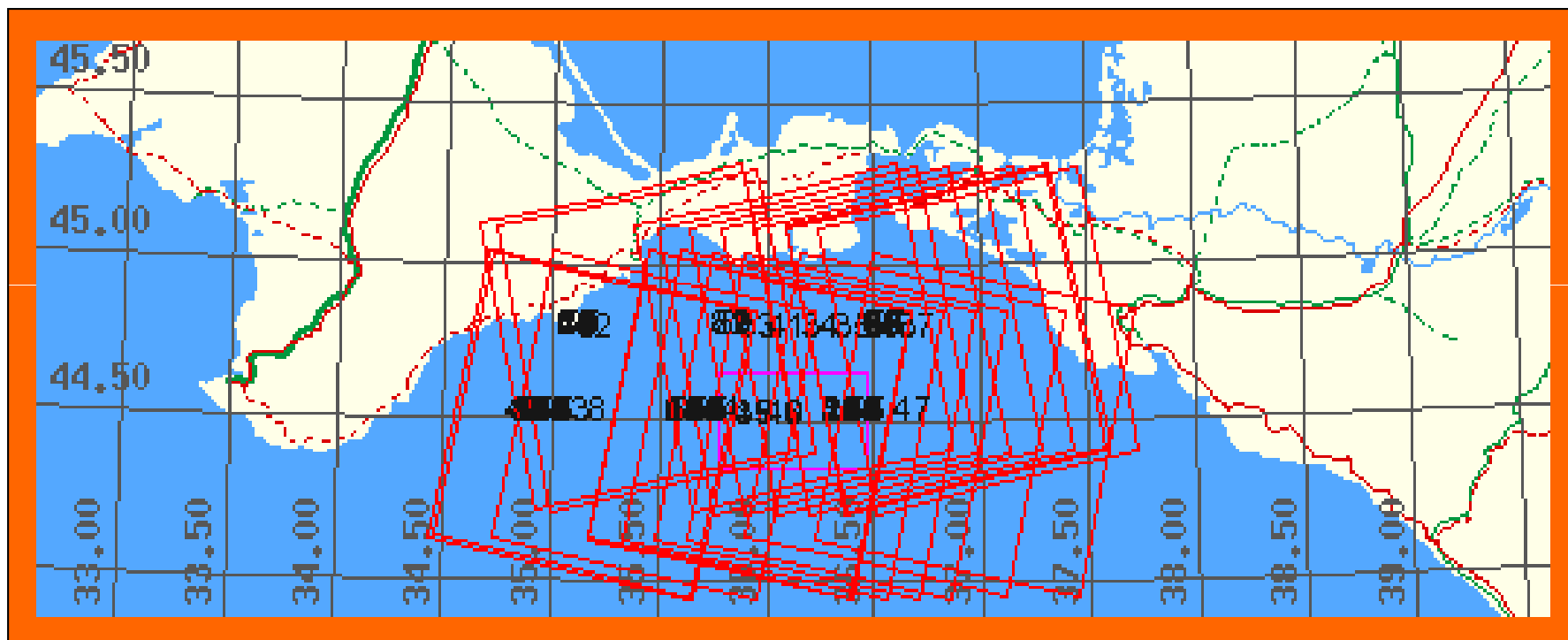
Geological cross-section

- Transpressional folds governs the geological structure



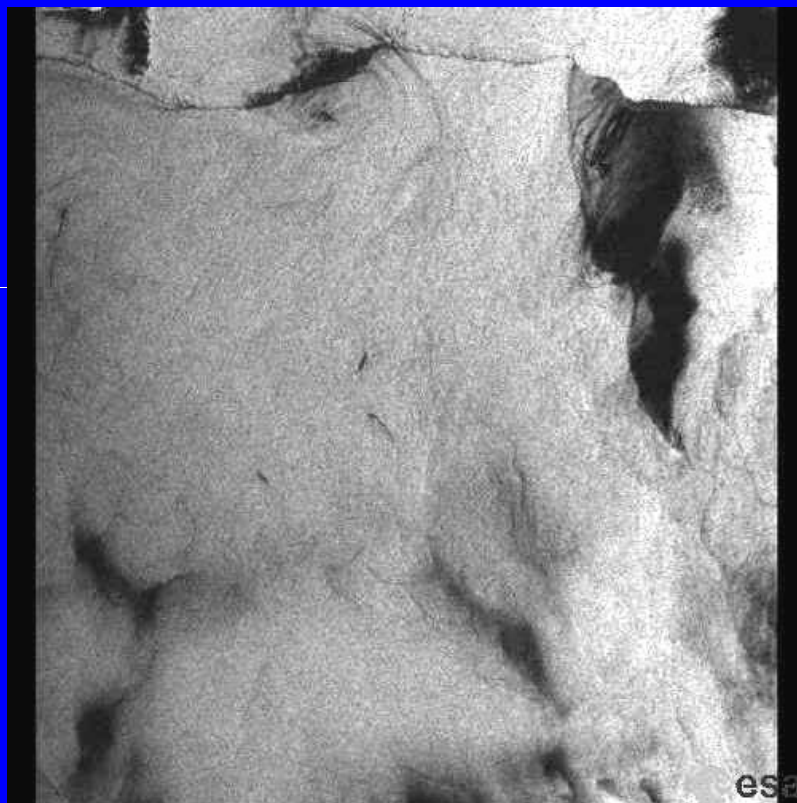
Dovzhok Ye.M. et al., 1996

Area of interest / *ERS* SAR Coverage



ESA Catalogue of satellite data on the area of interest contains 1290 *ERS*-SAR images for 1992 – 2003. Each *ERS*-SAR scene covers ~ 100x100 km. On the first stage of the study it was selected 230 quick-looks that suits the task and were analysed further

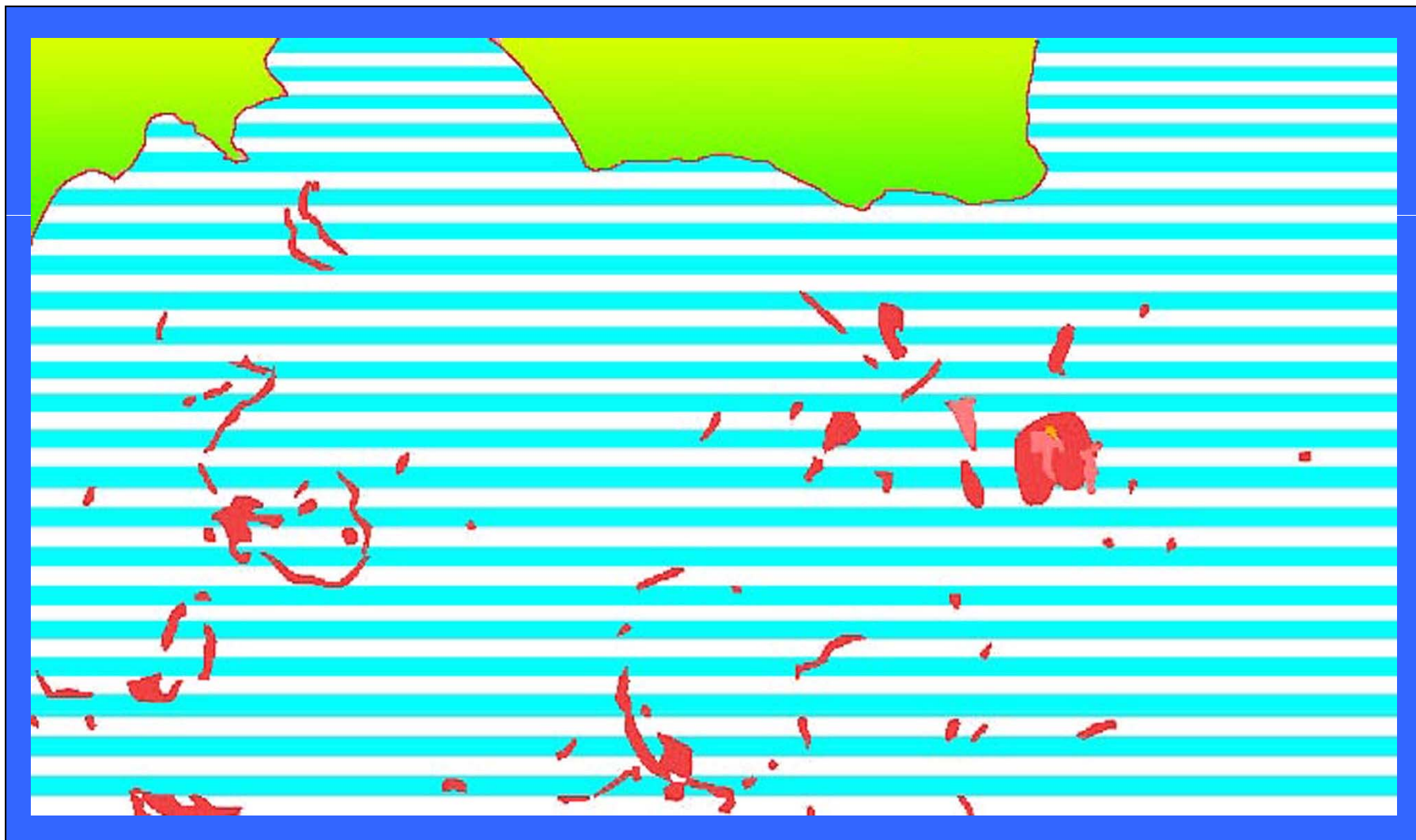
Interpretation – an example



■ **ERS – 1 scene (quick-look) of May 11, 1993**

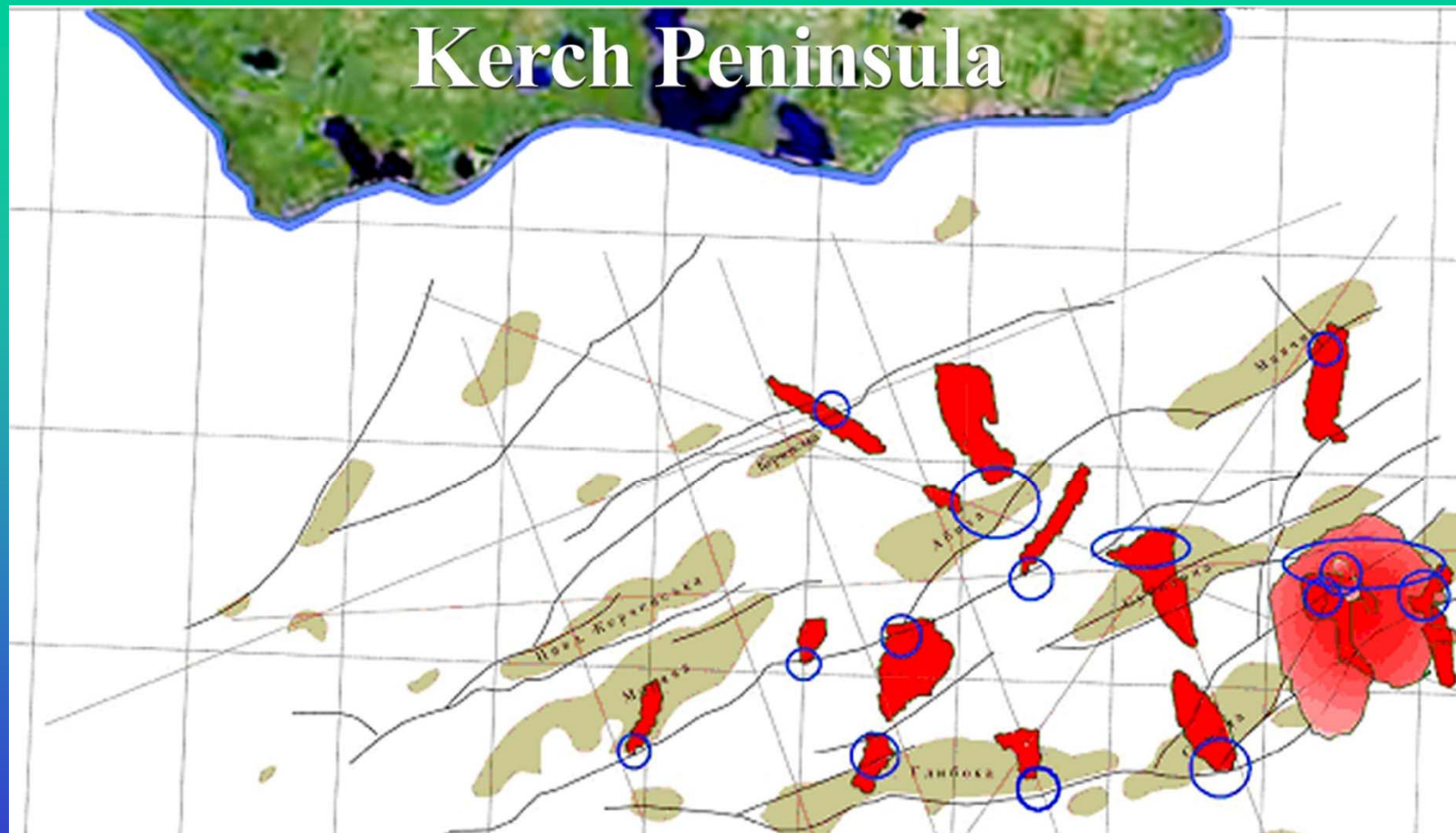
Cumulated useful signal

- Slick map, 22 selected *ERS-1,2* interpreted scenes



Target map

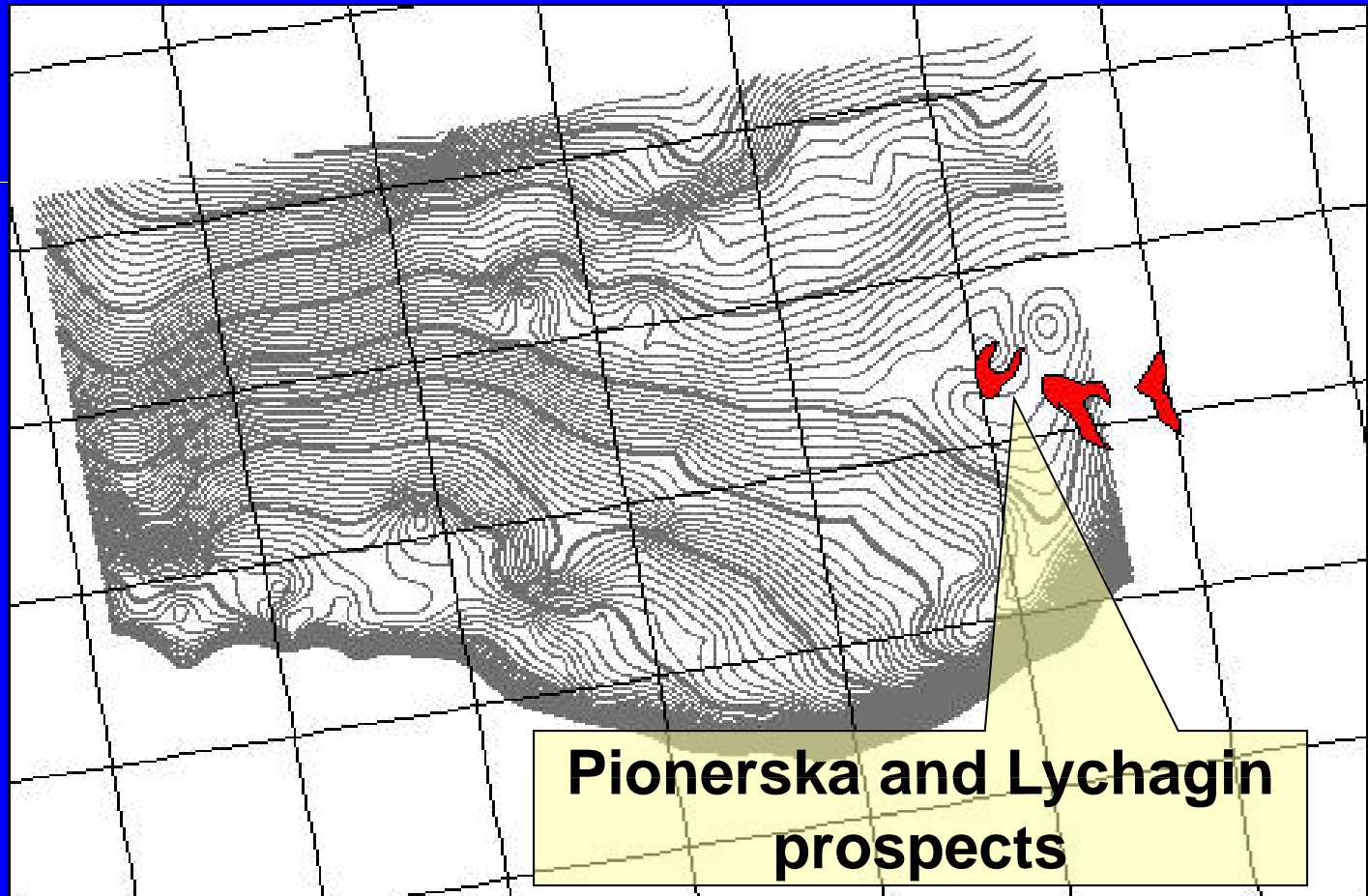
Kerch Peninsula



■ Natural oil slicks detected within South Kerch offshore according to interpretation of ERS SAR images for 1992-2003

Bathymetry

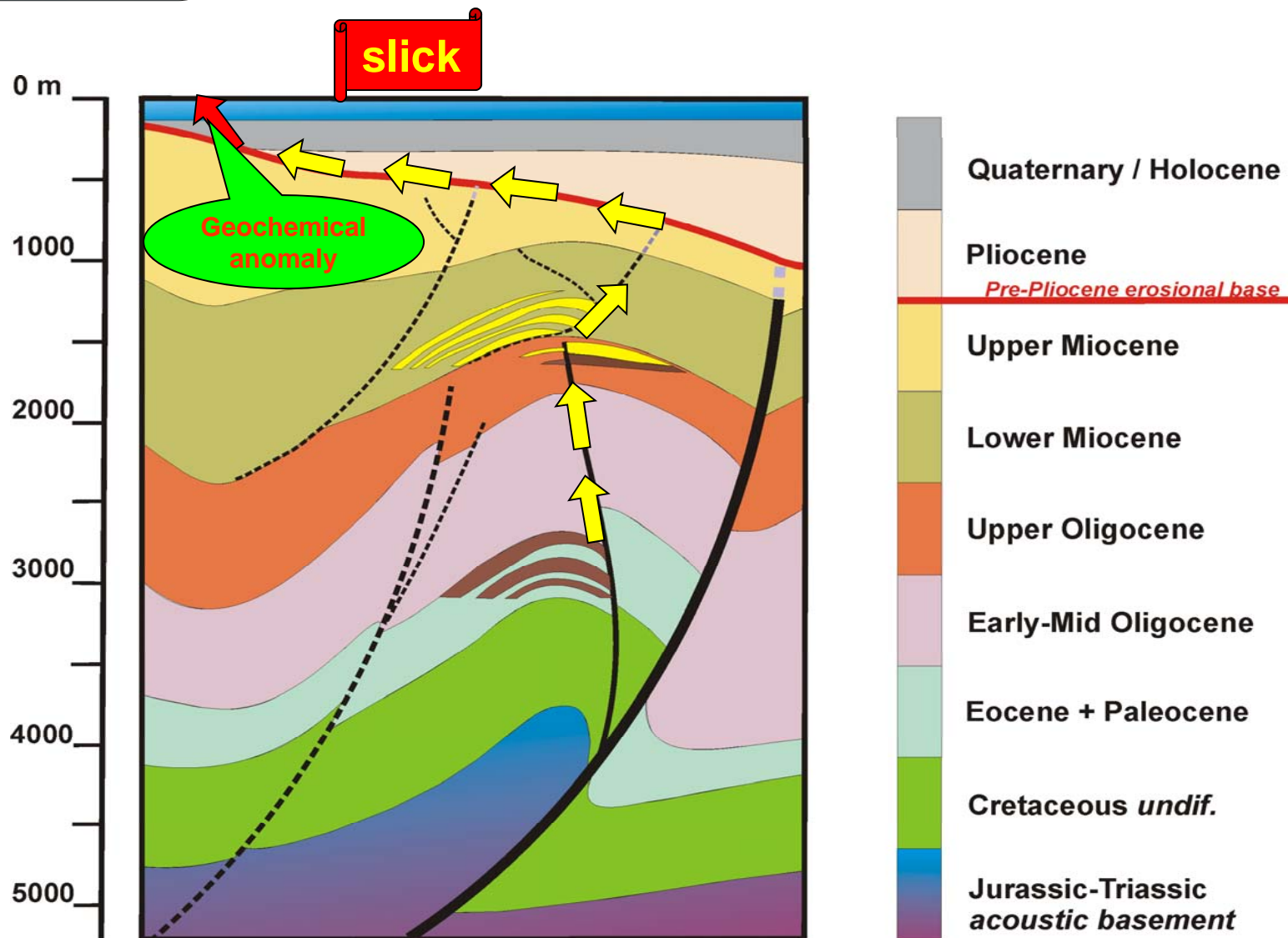
■ Sea floor relief and repetitive slicks points out on neotectonic control of seepages and deep-seated oil deposits, respectively



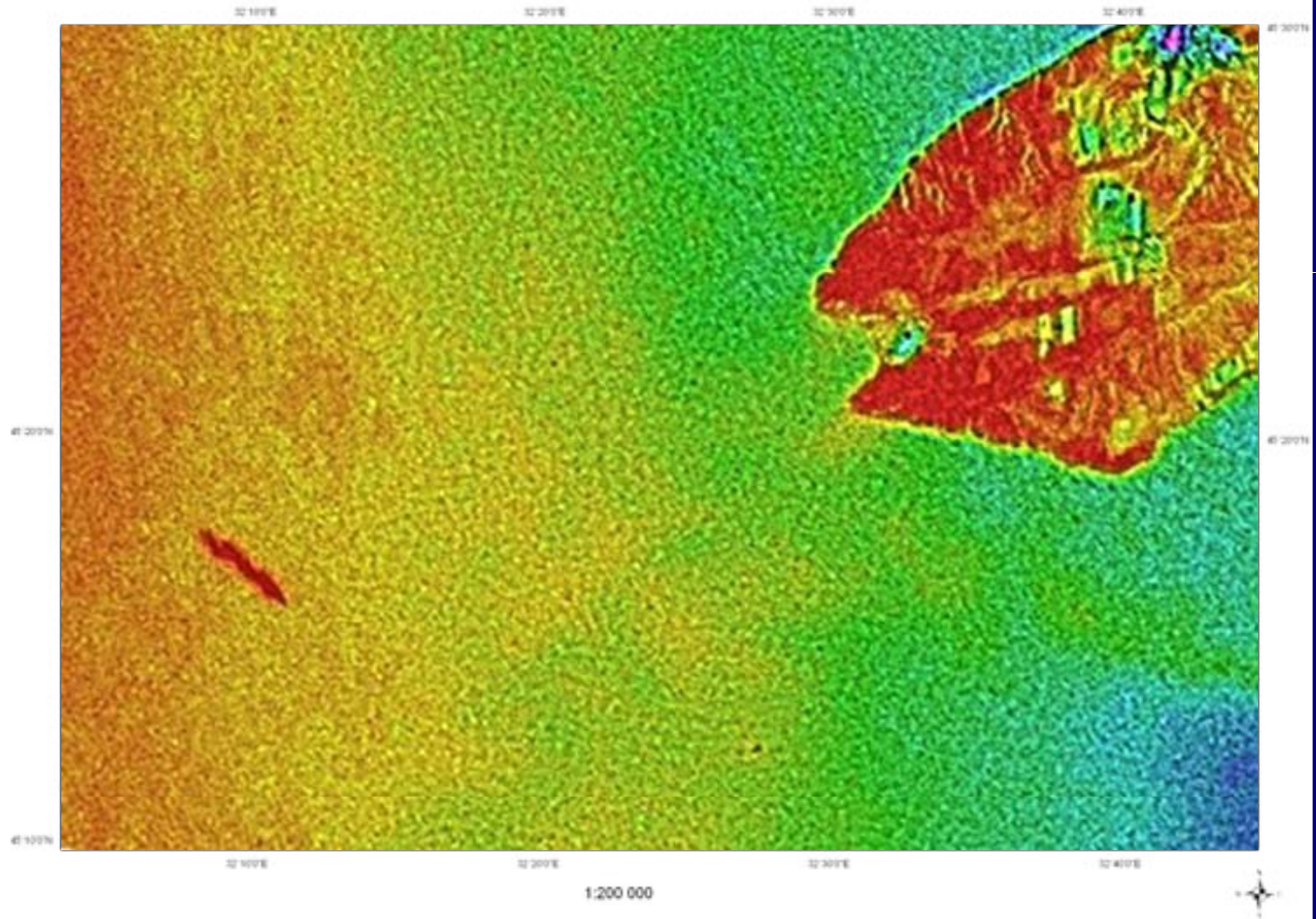
[illegible]

Bagriy I.D., 2003

Migration model

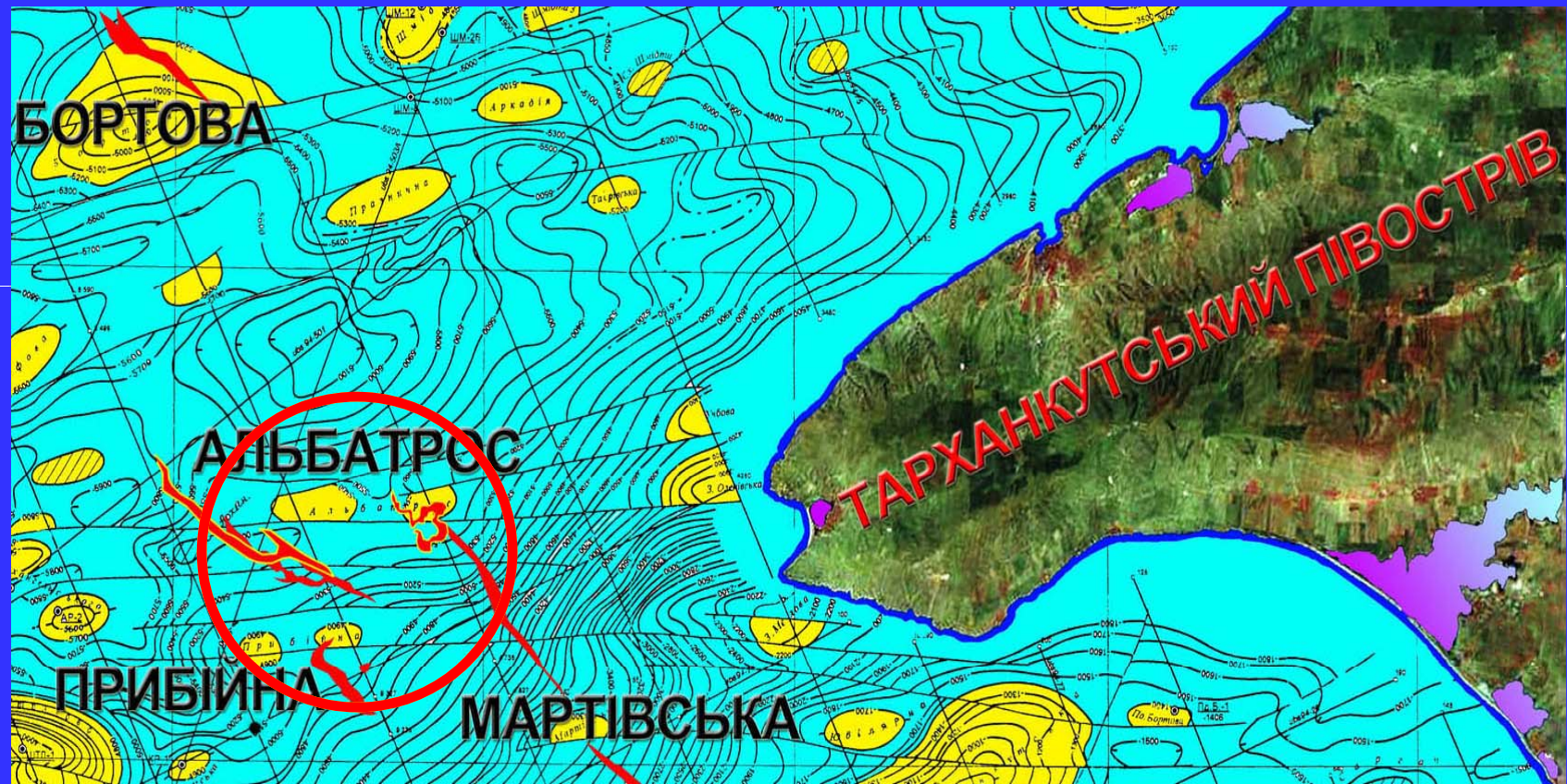


ERS-2 image



New hydrocarbon prospect

Thematic map (6 repetitions)



■ *ERS – 1* and *ENVISAT* images of 1991 та 2004, to the west of Tarkhankut Peninsula

New hydrocarbon prospect

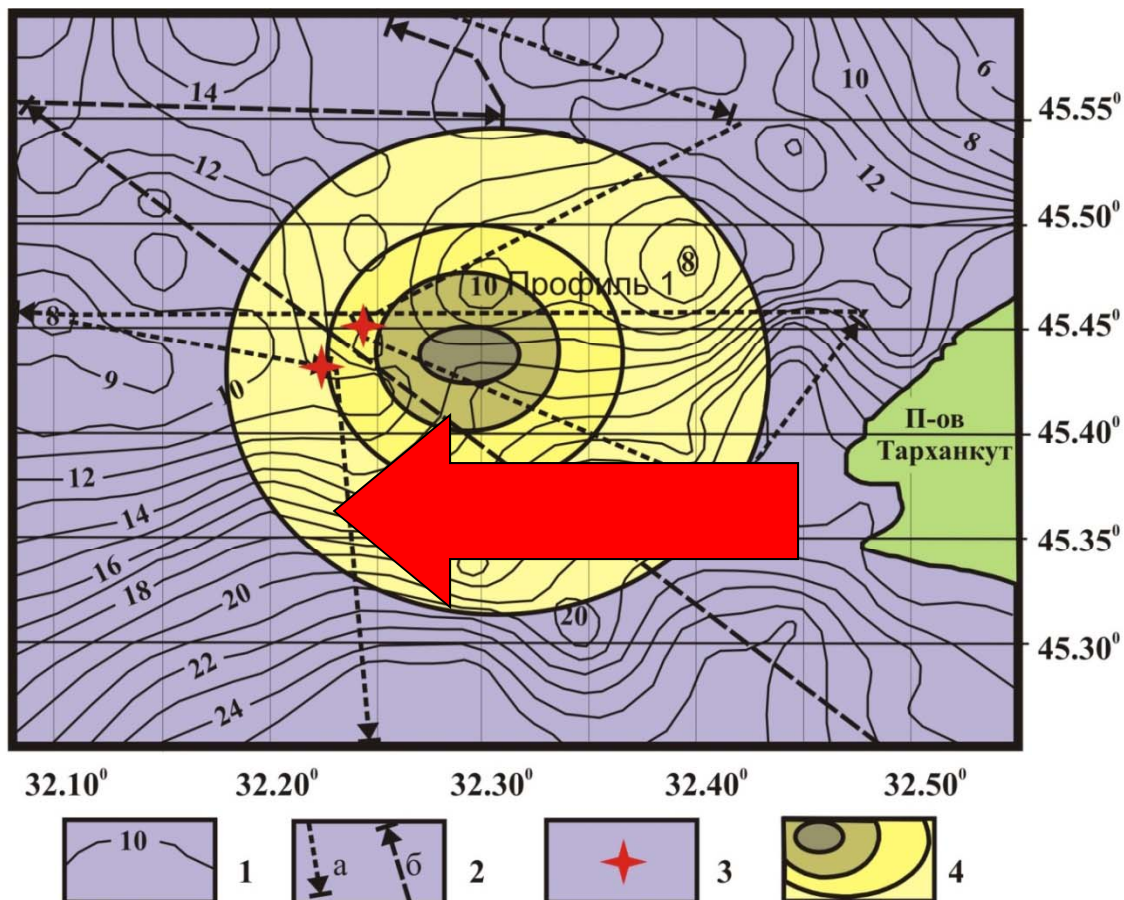


Рис. 3. Карта-схема аномалий поля силы тяжести в свободном воздухе в районе Западно-Тарханкутской аномалии. 1 - изолинии в мГл, 2 - расположение галсов геофизических наблюдений: а - прямой, б - обратный ход судна, 3 - станции геологического опробования, 4 - контуры Западно-Тарханкутской аномалии.

Conclusions 1

- Radar imaging is a reliable remote sensing tool for offshore oil and gas exploration using processing and thematic interpretation of space-born data coupled with analysis of available geological geophysical, hydrophysical and meteo information.
- The technique is based on rather simple but quite clear theory the prognostic power of which is proved by experiments, numerical modeling and exploration practice.
- Oil slicks are not ordinary anomalies of a radar image; first of all slicks are objects because they can reflect just that matter what we are searching for.
- The principle of stationarity of search features through criterion of repetition / spatial compactness of slick populations allow delineation of hydrocarbon seeps zones and improvement of prospects ranking and assessment owing to accumulation of useful signal.

Conclusions 2

- Results of this reconnaissance study is accepted by *SGE CHORNOMORNAFTOGAZ* and resulted in discovery of Subbotin oil field.
- It was found that typical slicks are much less abundant within Gulf of Odessa shelf comparing with Kerch Peninsula southern offshore that circumstantially evidences about dominant gas-prone hydrocarbon charge of the former one.

There is a lot of poorly understood features, processes and factors related to submarine seeps, oil slicks, and their images on radar scenes. Much should be done further to improve the theory and the technique ■