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SEA LEVEL AND PALAEOCLIMATIC CHANGES IN THE SOUTH AND MIDDLE CASPIAN SEA REGION SINCE THE LATEGLACIAL FROM PALYNOLOGICAL ANALYSES OF MARINE SEDIMENT CORES

ABSTRACT

A review of pollen, spores, non-pollen palynomorphs and dinocyst analyses made in the last two decades is proposed here. Building on spare palynological analyses before 1990, a series of new projects have allowed taking cores in the deeper parts of the Caspian Sea, hence providing access to low-stand sediment. However, still nowadays no complete record exists for the Holocene. The first steps towards quantification of the palynological spectra have been taken. Some of the most urgent problems to solve are the uncertainties related to radiocarbon dating, which are especially acute in the Caspian Sea.

KEY WORDS. Caspian Sea, pollen, dinocysts, Lateglacial, Holocene, climate, sea level

INTRODUCTION

The Caspian Sea has known many small and large-scale changes of its water level: c. 160 m in the last glacial-interglacial cycle and > 3 m in the last century [Kroonenberg et al. 2000]. In the latter period, these changes have had a dramatic impact on socio-economical activities around the sea [Kazancı et al., 2004; Leroy et al., 2010]. To reconstruct past sea level changes in the Caspian Sea (CS) and past climates of the region, the traditional approach so far has been to look at outcrops, to analyse their sediment and micro/macrofossil contents and to obtain radiocarbon dates on bivalve shells. Low stands are not recorded with this method otherwise than by a hiatus. The CS level variability is dominated by the variability of precipitation over the Volga River basin. At a longer timescale it is not impossible that other drivers of the water level played a role such as anthropogenic and tectonic ones.

Recently marine cores have been obtained in the shallow and more rarely in the deeper central and southern basins of the Caspian Sea (Fig. 1). Their multidisciplinary analyses covering both low and high stands holds the key to understanding firstly when sea level changes occurred, which is a step before understanding why they occur and secondly how climate changed, how fast and what were its drivers.

DRIVERS OF CASPIAN SEA LEVELS

In summer 2010, extreme temperatures well above 30 °C have affected Moscow for nearly two months. As a direct result of this and combined drought, extensive wildfires occurred in the Volga region. Global Climate Models have suggested that drought over the Volga basin would occur when ENSO is in La Niña phase [Arpe et al. 2000], and this is what occurred in 2010.

Figure 1a: Location of the Caspian Sea in relation to neighbouring seas;
1b: Location map of the cores and the main inflow in the Caspian Sea

Figure 2: Flooded mosque on N-E Iranian coast, view from the Ashoorade Island (Miankale Spit) to the Elburz Mountains (photo by S. Leroy in 2005)

Precipitation during summer plays a dominant role on sea level and this explains well the two major events that happened in the 1930s (drop) and after 1977 (rise) [Arpe and Leroy, 2007] (Fig. 2).

Nowadays the Volga River brings 80–85 % of the river water to the CS. However a few centuries ago, the Uzboi River (now defunct) brought water from the Amu-Darya [Létolle, 2000] a river whose source is in the Pamir and Tien-Shan and therefore its water is derived from the melting of monsoon-fed glaciers. Therefore the Caspian Sea water levels may be influenced both by climate of northern Europe and by climate over the western Himalayas.

PROXIES

Besides pollen (for example the former work of Abramova [1980] and Vronsky [1980] and the current work cited here) and non-pollen palynomorphs [Mudie et al., in press] a new proxy is being developed in the Caspian region, which is dinocysts. These small prokaryote organisms have many endemic forms in the Caspian region and it is only recently that their taxonomy has been firmly established [Marret et al., 2004] allowing now different scientists to use the same names and compare their data. Various forms, species and genera are related to different environments such as water salinity, water temperature, and nutrient content [Mertens et al., 2009]. Therefore this method is a proxy for sea-level changes. Plates 1 and 2 show some forms characteristic of the Caspian Sea and the Karabogaz Gol.

SURFACE SAMPLES

Surface samples are essential to interpret past changes, as they are a stepping stone to quantification by linking microfossil assemblages to environmental and climatic conditions (analogues). A collection of surface samples form useful training sets

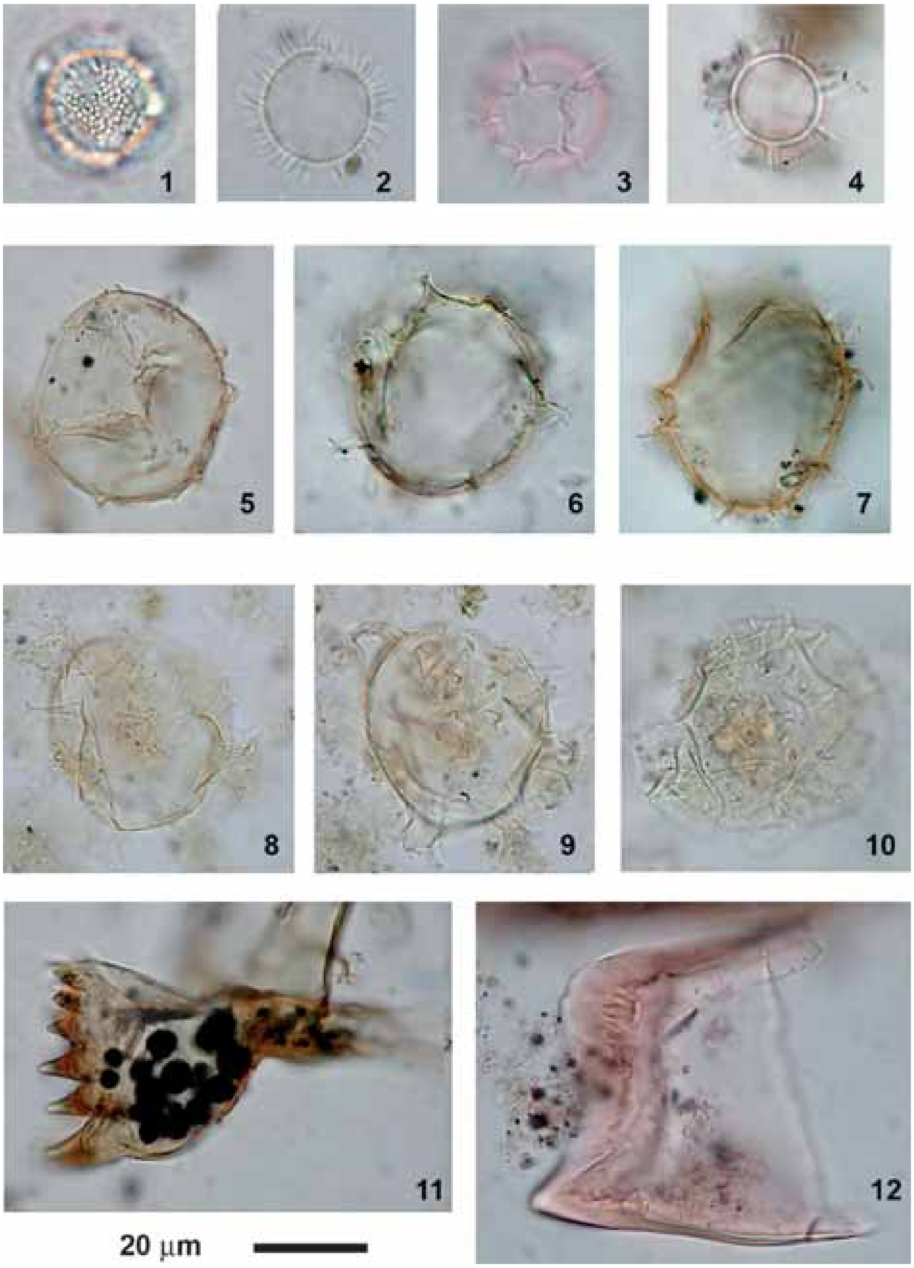

Plate 1: Photographs of palynomorphs of the Caspian Sea and the Kara-Bogaz Gol.

1. Incertae sedis 5b, fenestrate type of 5b, core SR94G05, I 70 cm.
2. Incertae sedis 5b, fenestrate type of 5b, other specimen, optical section, core SR94G05-I, 70 cm.
3. *Pterosperma*, core SR94CP14, 0–2,5 cm
4. *Pterosperma*, optical section, core SR94CP21, I 5 cm
5. *Impagidinium* caspienense, common type, core Gm2, 7–98 3,35 cm

6–7. *Impagidinium caspienense,* type with spiky processus, two different specimens, core SR94GS05, III 92 cm

8–9. *Spiniferites* belerius, core KBG8-01, 58–57 cm

10. *Lingulodinium machaerophorum* var. A, which is a form typical of the Kara-Bogaz Gol, core KBG8-01, 58–57 cm
11. Mandible of ostracod, core Gm2, 7–98 3,35 cm
12. Tooth of gastropod radula, core SR94CP14, 20 cm

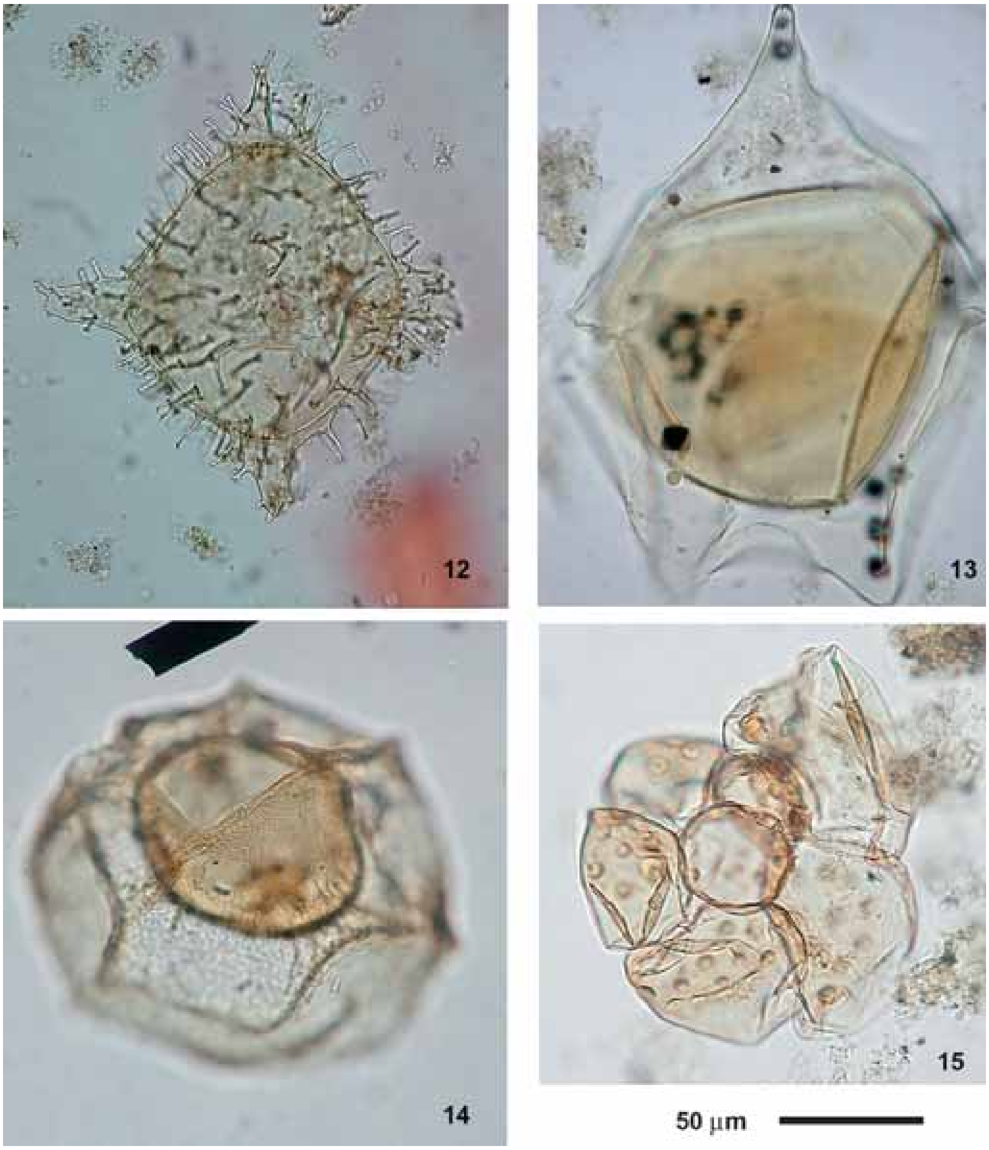

Plate 2: Photographs of palynomorphs of the Kara-Bogaz Gol.

15. Foraminifer lining, core KBG8-01, 18-19 cm

Reworked dinoflagellate cysts of the Karabogaz-Gol

12. Wetzeliella, core KBG8-01, 18–19 cm
13. Deflandria, core KBG8-01, 18–19 cm
14. Unidentified dinocyst, core KBG8-01, 17–18 cm

and allows using pollen/dinocyst-based palaeoclimatic reconstructions such as transfer functions. So far for pollen, some spectra have been published in Kazancı et al. [2004] for the lagoon of Anzali in N. Iran and in Djamali et al. [2009] in the Golestan National Park in NE Iran. These, along side unpublished data, show the very open character of the landscape around the CS: steppe (dominant *Artemisia* pollen) and desert (dominant Chenopodiaceae pollen) and the forested area in the south and southwest. These forests still contain some elements that have survived from the Tertiary and which have disappeared from Europe, such as *Parrotia persica* and *Gleditsia caspica*.

For the dinoflagellate cysts, some modern assemblages have been published from core tops [Marret et al., 2004] across the south and central basins and from grab samples in the lagoon of Anzali [Kazancı et al., 2004]. Typical modern samples are dominated by *Impagidinium caspienense* and correspond to a brackish salinity of 12–13.

DATING

Radiocarbon dating is the best tool to date the sea-level changes of the Caspian Sea over the last 40,000 years. However no detailed studies have been made so far of its marine reservoir effect. This is well known to skew radiocarbon dating due to old carbon present in the water and being incorporated in living organisms as they grow [Ascough et al., 2005]. The magnitude of this effect is not the same in all locations and at all times. For the world ocean a reservoir correction of 400 years is generally accepted. Some experiments made in Israel have however shown that a reservoir effect of up to 2000 years may happen. In the case of volcanic fumaroles, a reservoir effect of up to 1500 years has been noted due to the release of old CO_2 [Higham, no date].

Preliminary work on radiocarbon in the Caspian Sea has shown that many different sources of old carbon exist, as well as other negative influences on the quality of radiocarbon ages: old carbon in the water, effect of various types of methane seepages, activity of surface waters (108–117 pMC) and detrital carbonates and/or detrital organic matter [Escudié et al., 1998; Leroy et al., 2007]. Various reservoir effects have been used to correct radiocarbon dates in the literature. They range from 290 to 440 yr: 383 yr in Leroy et al., 2007; 290 yr in Kroonenberg et al. [2007]; and 390–440 yr in Kuzmin et al. [2007]; and 345 to 384 yr in Karpytchev [1993]. This poor precision needs to be resolved. The best material to date would be remains of terrestrial plants, which are however quite rare in marine cores.

For the more recent times, i.e. the last 150 years, the radionuclid method is the best, either ^{210}Pb alone or in combination with ^{137}Cs. The combination of radiocarbon and radionuclid methods however still leaves a gap between AD 1750, the most recent reliable radiocarbon ages due to a subsequent plateau, and AD 1860, the oldest age obtained by radionuclids.

THE LAST FEW CENTURIES

Palynological analyses (pollen and dinocysts) of a sediment core taken in the Kara-Bogaz Gol (KBG) in the frame of an INCO-COPERNICUS project have been used to reconstruct rapid environmental changes over the last two centuries (chronology based on ^{210}Pb) [Leroy et al., 2006]. A natural cyclicity (65 years) of water level changes in the CS [Kroonenberg et al., 2000] and in the KBG [Giralt et al., 2003] and anthropogenic factors (building of a dam separating the CS and the KBG waters) combine to induce rapid changes in water levels of the KBG, in the salinity of its waters and in vegetation cover of its surroundings. The impact of low water levels on the dinocysts is marked by a lower diversity and the survival of two species that are typical of the KBG, the CS species present in the KBG having disappeared. During periods of higher water levels (AD 1871–1878), the lake is surrounded by steppe-like vegetation dominated by *Artemisia*; whereas during periods of low water levels (AD 1878–1913 and AD 1955–1998), the emerged shore are colonised by Chenopodiaceae. The period of AD 1913–1955 corresponding to decreasing water levels has an extremely low pollen concentration and a maximum of reworking of arboreal taxa.

Two short marine cores (c. 150 cm) have been taken off shore the coast of Iran (core CS03 off Anzali in the west and core CS10 off Babolsar in the centre) at water depths of 250 m [H. Lahijani, pers. comm.]. The sequences cover the last 200 years according to radionuclid profiles. Unpublished data indicate that the dinocyst assemblages are dominated by *Impagidinium caspienense* with increasing

Lingulodinium machaerophorum towards the top. The pollen spectra are dominated by *Artemisia* and Chenopodiaceae off shore Anzali, whereas *Alnus* is very abundant off shore Babolsar.

The coastal lagoons of Anzali (core HCGA05, 170 cm long) and Amirkola (core HCGL02, 100 cm long) have been cored by the Iranian National Institute of Oceanography (INIO). The radiocarbon dates on shells combined with radionuclids indicate high but very varying sedimentations rates depending on locations. Palynological analyses of Anzali revealed the continuous existence of a slightly brackish lagoon over the last centuries and of Amirkola (analyses made jointly with M. Djamali) show the progressive closing up of the water body [Leroy et al., accepted]. Higher sea levels at the base of these two records have been related to the Little Ice Age. The strong influence of the Sefidrud River and other small rivers flowing from the Alburz Mountains, which carry huge volumes of sediment to the sea, is probably the main driver of these changes with sea level coming in second position.

THE LATE HOLOCENE

Pilot cores (140–182 cm long) have been taken in the south basin, the middle basin and the northern part of the middle basin during a French–Russian oceanographic cruise (August 1994), on board a Russian military ship, rented for the sea cruise in the frame of the same INCO-COPERNICUS project. Core locations were in deep water, and were chosen to avoid direct river influence (SR01GS9414CP or in short CP14 in the south basin, 330 m; SR01GS9418CP or CP18, 480 m in the central basin; and SR01GS9421CP or CP21, 460 m depth in the north of the central basin). A chronology available for one of the cores is based on calibrated radiocarbon dates (ca 5,5–0,8 cal. ka BP) on bulk sediment corrected for their detrital content [Leroy et al., 2007].

Pollen, spores and dinoflagellate cysts have been analysed on these sediment cores [Leroy et al., 2007]. The pollen and spores assemblages indicate fluctuations between steppe and desert. In addition some outstanding zones display a bias introduced by strong river inflow. The dinocyst assemblages change between slightly brackish (abundance of *Pyxidinopsis psilata* and *Spiniferites cruciformis*) and more brackish (dominance of *Impagidinium caspienense*) conditions.

During the second part of the Holocene, important flow modifications of the Uzboy River and the Volga River as well as salinity changes of the Caspian Sea, causing sea-level fluctuations, have been reconstructed. A major change is suggested at ca 4 cal. ka BP with the end of a high level phase in the south basin (core CP14). Amongst other hypotheses, this could be caused by the end of a late and abundant flow of the Uzboy River, carrying to the Caspian Sea either meltwater from higher Eurasian latitudes or water from the Amu-Darya and the western Himalayas. A similar, later clear phase of water inflow has also been observed from 2,1 to 1,7 cal. ka BP in the south basin and probably also in the north of the middle basin.

THE EARLY HOLOCENE AND LATEGLACIAL

A further two cores from the same cruise of 1994 are being analysed for the pollen and dinocyst content. These Kullenberg cores are each 10 m long [Chali'@e et al., 1997]. Core GS05 from the south basin (museum number SR01GS9405) was taken in a slightly different coring station than core CP 14, i.e. in a more southerly location, but the two cores seem to overlap for a millennium. Core and core GS18 from the middle basin (museum number SR01GS9418) comes from the same station than core CP 18 [Leroy et al., 2007]. However preliminary dating on ostracod shells suggests that no overlap occur between the pilot and the Kullenberg cores due to severe losses at the top of the Kullenberg cores during corer penetration.

The pre-Holocene sediment of the long core from the south basin is silicate rich. Preliminary results suggest a very open landscape during the Lateglacial with intensive mechanical weathering in a cold climate and high water levels [Leroy et al., 2000; Pierret et al., in prep.]. At the beginning of the Holocene, the sedimentation switches to carbonates and the water level drops. A progressive colonisation by shrubs takes place and the erosion becomes chemical. The development of trees is delayed and they become more abundant only after 4000 cal. yr BP in line with a further increase of chemical erosion.

The dinocyst assemblages of the middle basin core show a late change from slightly brackish water to more brackish water (as in the present) only at 4 cal. ka and not at the transition to the Holocene. The dinocyst assemblages of the southern core change at 9,5 cal. ka BP, but from the present day values of salinity (brackish) to a lower salinity. This period of lower salinity correspond to that seen at the base of core CP14, which terminates at c. 4 cal. ka BP. Therefore the two basins did not have the same water level history giving a possible role to the Apsheron sill.

CONCLUSIONS

In the absence of a complete palynological record for the Holocene, much remains to be done in the Caspian Sea. In the near future a transfer function for pollen and dinocysts should be developed at the scale of the whole sea. Palaeoclimatic records from continuous fine-grained marine cores covering a whole climatic cycle with robust age-depth model are cruelly needed [Cordova et al., 2009].

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