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Studies in Caspian Palynology: Six Million Years of Vegetation, Climate and Sea Level Change

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This thesis highlights some of the key geological, biostratigraphic, biological, geographical and climatic events that have shaped the depositional history of the Caspian Sea over the last 6 million years. Part 1 focuses on the late Pleistocene to present day. Part 2 is based on older geological records from the latest Miocene to early Pleistocene.

Part 1: 'the present is the key to the past'

Chapter 2 presents the results of a multi-disciplinary study of core samples and surface samples from the lower Volga Delta, in the Damchik region of the Astrakhan Man and Biosphere Reserve. Palynological analyses were undertaken on 231 samples from eight cores of Holocene age with supplementary information obtained from selected analysis of core samples for ostracods and nine surface samples studied for palynology and ostracods. Four main phases of delta development were recognised during the Holocene. Phase 1 occurred during the early Holocene prior to ca. 9000 yr BP and is a depositional record of the Baer Hills ('Baery knolls'), the desert dunes associated with the Mangyshlak lowstand when Caspian Sea level was ca. 80 m below its present level. Phase 2 records brackish dinocysts in low-lying parts of the delta, suggesting a gradual rise in Caspian Sea level after ca. 8900 cal. yr BP. Increased Chenopodiaceae-Amaranthaceae pollen between ca. 7820 and 7720 cal. yr BP may be related to the northern hemisphere '8200 year BP cold event'. Phase 3 commenced at ca. 3770 cal. yr BP, marked by increases in arboreal pollen (e.g. *Quercus, Ulmus, Tilia* and *Carpinus*) and brackish dinocysts (e.g. *Spiniferites cruciformis, Impagidinium caspienense* and *Pterocysta cruciformis*), suggesting an expansion of woodland vegetation and varying Caspian Sea levels. Phase 4 after ca. 1850 cal. yr BP records incision of the delta and sediment inversion during the Derbent lowstand (ca. 1180 to 570 cal. yr BP) at around the time of the 'Medieval Warm Period', followed by a landward expansion of '*avandelta*' aquatic vegetation, likely to equate with the 'Little Ice Age' Caspian Sea highstand. Chapter 2 also presents a comparison of the modern Volga Delta with the Mio-Pliocene palaeo-Volga Delta.

Chapter 3 extends the record from the northern coastal region into the late Pleistocene in deposits from the Emba-Ural Delta region of Kazakhstan, and is based around a sedimentological and biostratigraphic study of six cores taken in the shallow water offshore area. Four stratigraphic units are visible on seismic profiles and constrained by radiocarbon ages within the range of >43,500 to 390 ± 40 ^{14}C yr BP. Unit 4 is interpreted as a desert dune system, similar to the Baer Hills but significantly older, linked with the Atelian lowstand of the Caspian Sea during MIS 4. Samples studied for radiocarbon from this unit are beyond the dateable range. Unit 3 is argillaceous and was deposited during MIS 3 in a shallow open water or lagoonal setting, based on its ostracod faunas. Unit 2 is sandy and interpreted as a partial barrier bar complex deposited during MIS 2, prior to the Last Glacial Maximum. Unit 1 is a thin marginal marine deposit of Holocene age. The palynological records are unlike any previously observed from the Caspian Sea. Dinocyst assemblages show a change from dominance by *Pterocysta cruciformis* in Unit 4 to *Impagidinium inaequalis* in Unit 3, possibly a response to a warming climate and / or increasing salinity. The pollen floras also show significant change, including frequent pollen from thermophilous-hygrophilous trees (e.g. *Glyptostrobus pensilis*) in Unit 3. If in situ, this would indicate that the Emba-Ural Delta region was a 'refugium' for plants of East Asian affinity during MIS 3.

Part 2: 'the past is the key to the present'

Chapter 4 documents a palynological, biostratigraphic and sedimentological study of 282 outcrop samples, collected mainly in the Kirmaky Valley and Yasamal Valley localities in Azerbaijan. The main objective was to interpret the depositional environments of the Productive Series (PS), the main oil and gas producing rocks in the western, central and south Caspian region. No new age information was provided, but the consensus of opinion supports Soviet-era assertions that the PS was deposited during the Pliocene between ca. 5.3 Ma and 2.71 Ma. The samples were mainly obtained from the late Miocene 'Pontian' and the Pliocene PS and palynological data interpreted by means of multivariate statistical analyses. 'Pontian' sediments contain mainly brackish lacustrine palynofloras which occur above a marine-influenced flooding event, dated at 6.12 Ma by van Baak et al. (2016). There is an indication of a drying climate towards the end of the 'Pontian' that could be coincident with the Messinian Salinity Crisis, but there is no direct evidence for a significant base level reduction in the Caspian Sea at this time. Palynological assemblages from the Kirmaky Suite of the Lower Productive Series (LPS) show depositional environments ranging from fluvial to deltaic-lacustrine. Sand bodies are interpreted as mostly fluvial, with mudstones and siltstones representing lacustrine flooding events. LPS deposition ended with the NKG clay, a largely red-bed succession interpreted as a basinward migration of fluvio-lacustrine facies. The Pereryv-Fasila and Balakhany Suites of the Upper Productive Series (UPS) consist mainly of fluvial sands. Palynofloras from clay and siltstone beds indicate deposition mostly within fluvial and / or alluvial settings with terminal splays, and flood plain lakes and ponds present. Muds within the overlying Sabunchi Suite were deposited mainly in freshwater to saline flood plain lakes. Minor 'Caspian Lake' incursions in the UPS are suggested by the sporadic presence of brackish dinocysts. Deposition is likely to have been strongly influenced by changes in climate and discharge from the Volga and Kura rivers. There is a suggestion of cyclical deposition evident from the palynological assemblages from the Kirmaky Suite, which recur over intervals of ca. 80 to 100 m. Further investigation is required but it is possible that these relate to 100 kyr eccentricity cycles of orbital forcing.

UPS deposition ended with deposition of the sand-prone Surakhany Suite, which is the subject of a sedimentological and palynological study in Chapter 5, based on outcrop data from two localities in Azerbaijan. The Lokbatan locality, situated on the Apsheron Peninsula, has mainly mudstone sediments with rare channelised and sheetflood siltstones and sandstones sourced from the Russian Platform via the palaeo-Volga. The Babazanan locality, situated about 100 km to the south-west, has numerous stacked and laterally extensive sandstone bodies and fewer mudstone units. A Lesser Caucasus volcanic source, distributed via the palaeo-Kura, is inferred for most of the Babazanan sandstones. Multivariate statistical analysis of palynological data from 58 outcrop samples shows that there is considerable variation within the assemblages, with differences attributed to the site of deposition and the relative extent of arid, humid, freshwater and saline influences. Deposition at Lokbatan occurred primarily on a flood plain or exposed alluvial plain, with algal assemblages suggesting the presence of ephemeral freshwater to saline lakes and ponds. The assemblages from Babazanan show a greater extent of shallow water influences, but contained within a flood plain setting. No brackish dinocysts were recorded, implying that 'Caspian Lake' influences were not significant in the Surakhany Suite at the studied localities.

PS deposition across the central and southern Caspian region continued almost until the end of the Pliocene (Piacenzian) and that termination is marked by a sharp lithological boundary, typically from olive-brown silty sands and muds of the UPS to grey muds and fine-grained clastics of the Akchagylian (Akchagyl) and overlying Apsheronian (Apsheron) Series. Chapter 6 is a study of pollen and spores obtained from sediment cores and outcrops in the North Caucasus (the Caucasus Mineral'nyye Vody region, the Tersko-Sunzhensky area and the foothills of Dagestan), and provides a picture of past vegetation and climate change for the late Pliocene to early Pleistocene. The lower Akchagyl is characterised at first by an open landscape dominated by steppe vegetation that was subsequently replaced by forests with thermophilic relicts, consistent with climatic warming at around 3.2 Ma. This is probably related to the 'Mid Pliocene Warm Period'. During the middle-upper Akchagyl and Apsheron periods, the vegetation cover of the North Caucasus gradually changed, with forests replaced by steppe in response to episodes of aridification. Many of the tree genera represented in the pollen records are remnants from the 'Turgai Flora' that originated from Paleogene Boreal-Arctic temperate forests which persisted in Eurasia following the closure of the central Asian 'Turgai Seaway' during the Oligocene. Inconsistencies in inferred ages and lithostratigraphic nomenclature around the Plio-Pleistocene transition are highlighted.

Chapter 7 presents new palynological, ostracod and foraminiferal data from a long outcrop section in the Jeirankechmez River valley, Azerbaijan, near the western coast of the Caspian Sea. More than 100 samples were studied for palynology, ostracods and foraminifera, of which 64 are from the latest

Pliocene to early Pleistocene intervals, representing the uppermost part of the Pliocene PS and the overlying Plio-Pleistocene Akchagyl and early Pleistocene Apsheron regional stages. Akchagyl deposition is associated with a significant flooding event that, at its maximum extent, reached the Sea of Azov and into present day Iran, Kazakhstan, Turkmenistan and Russia. Palynology and ostracod data show that the lowermost beds of the Akchagyl at the Jeirankechmez locality contain predominantly freshwater assemblages and only minimal marine or brackish content, suggesting that the onset of Akchagyl deposition was not necessarily a marine induced event. Reworked Mesozoic palynomorphs occur frequently in this lowermost interval, including the pollen taxa *Aquilapollenites-Triprojectus* and *Wodehousia* that are mainly found in situ at localities to the north of 55 to 60° N. Significant marine influence is evident ca. 30 m above the base of the Akchagyl, marked by the '*Cassidulina* Beds' which contain a distinct, low diversity assemblage of foraminifera that occurs widely and can be correlated in many parts of the greater Caspian region. Morphometric analyses of these foraminifera show that they are most closely associated with *Cassidulina reniforme*, a cold water species most often found in the Arctic Ocean. However, new data are presented in this study which show for the first time that *C. reniforme* did extend its range into the Mediterranean (Adriatic) Sea in at least one cold stage during the late Pleistocene. The findings open up the possibility of a marine connection from the Arctic Ocean to the Caspian Sea coincident with the onset of northern hemisphere Pleistocene glaciations, although this remains speculative. Other possibilities for the dispersal of these foraminifera are via incidental vectors such as birds, aquatic fauna and ice-rafted debris. An interval more than 300 m thick is assigned to the Apsheron stage on the basis of largely brackish ostracod and dinocyst associations. The dinocysts are of 'Peri-Paratethyan' affinity and most closely resemble species first described from Miocene sediments in the Pannonian Basin of Eastern Europe. Many similarities exist in the microplankton records (dinocysts and acritarchs) between the Caspian Sea, the Black Sea and central Paratethys and are reported for the first time.

Caspian palynofloras from the middle Pleistocene and early part of the late Pleistocene are the subject of ongoing research and are referred to in several abstracts in the Appendix of the thesis. The Caspian Sea that we see today is the result of a continuing process of basin isolation and periodic reconnection with the world's oceans.