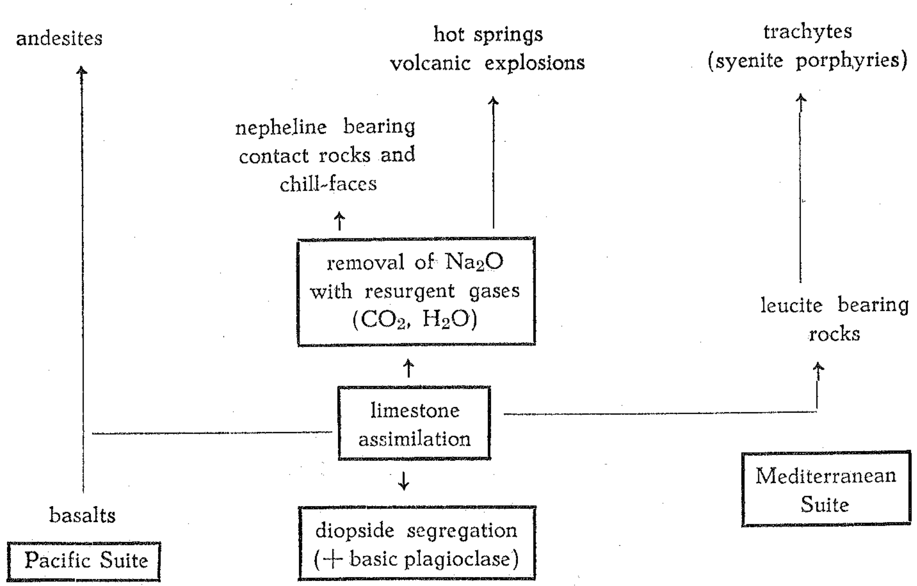
Meanwhile part of the soda of the magma escaped with the resurgent gases into the contact aureole, or by volcanic explosions, because soda has a greater affinity to carbondioxyde than potash. This escape of the soda appears from the presence of sodic minerals, such as nepheline, in the above described chill-face and in the contact metamorphic limestones.

It is conceivable that especially along the contact an upward current of resurgent gases occurs, carrying along Na_2O as a chemical compound. This marginal contact zone was suddenly cooled down during the eruption and consolidated into a chill-face, in which the sodium-felspatoid (nepheline) could crystallize, whilst also the diopsidic pyroxene phenocrysts were partly altered by a kind of autopneumatolysis into a sodium-rich, aegirine-like pyroxene. Consequently, this chill-face assumed the appearance of a sodium-rich Atlantic rock type. Such in contradistinction to the bulk of the magma, which belongs to the Mediterranean suite. In the latter the potash felspathoid (leucite) could be formed, due to the desilication and the passive enrichment of the potash content.

In the later stages of the eruption cycle more leucocratic rocks were produced (trachytes, syenite-porphyry dikes). These rocks might be interpreted as the result of progressive crystallization differentiation in the hearth.

On account of these observations and considerations it seems to be very probable, that the Mediterramean kindreds of the Muriah complex were derived from the Pacific magma type by a "pathological" side branch of differentiation caused by intensive limestone assimilation, according to the following scheme:



Oceanography. — *On the desirability of a research into certain phenomena in the region of upwelling water along the coast of South West Africa.* By MARGARETHA BRONGERSMA—SANDERS, D.Sc. (Communicated by Prof. H. BOSCHMA.)

(Communicated at the meeting of May 31, 1947.)

In some bays on the coast of South West Africa (especially in Walvis Bay) and sometimes also in the open sea outside of them a mass mortality of fish takes place periodically. Some mortality takes place every year; very great mortalities, however, occur in some years only. They occur always in the southern summer; very great mortalities occur mostly in December and especially at Christmas time.

The surroundings of Walvis Bay are further characterized by a very peculiar sediment on the sea bottom (see VON BONDE, 1928; MARCHAND, 1928; COPENHAGEN, 1934). The peculiarites of this sediment are the following: the presence of a great quantity of H_2S; a high organic content; nearly complete absence of living organisms (benthonic invertebrates, the scavengers of the seabottom are absent!), anaerobic bacteria excepted; abundance of fish remains; a very high % of skeletons of diatoms. I must stress the fact, that the peculiarities of this sediment are not caused by stagnation of the lower water layers. Besides in the Walvis Bay itself the sediment occurs also in the open sea outside it; and there is, as far as I am aware, no barrier preventing circulation whatever. The area, in which this sediment occurs, stretches nearly from Cape Cross to south of Conception Bay (21° 30'—24° 30' S), a distance of approximately 200 miles and from the coast line 25—30 miles west (i.e., about to the 77 fathom line). On account of the absence of living organisms in the sediment the area is called the Azoic zone of the West coast. In this area there is a coastal belt between the Azoic zone and the shore extending from Pelican Point to 23° 38' S where the bottom consists of fine grey sand, and the absence of green sulphurous mud being noteworthy.

Hypotheses put forward in recent publications (REUNING, 1925; MARCHAND, 1928; CLASSEN, 1930; COPENHAGEN, 1934) agree in the supposition, that H_2S is the cause of the mortality, although opinions differ as to the origin of the gas. Except COPENHAGEN the authors agree, that the H_2S derives from sulphur compounds of the land, and is brought to the sea by the river Kuiseb; the coast region being very rich in sulphur minerals. According to MARCHAND sulphides and sulphates are carried down as such by the Kuiseb and broken up by chemical action with the sea water setting free noxious compounds and gazes fatal to fish. The periodicity of the mortality is explained by MARCHAND by the periodical rainfall in the hinterland and consequently by the periodical emanating of water of the Kuiseb river (the lower course of this river is choked up with sand and communication with the sea is by seepage only) on the bottom of the bay (Kuiseb underground water hypothesis). CLASSEN undependently arrived at nearly the same hypothesis. REUNING although an adherent of the Kuiseb underground water hypothesis contends, that this is not the sole cause, but that there exist beds of pyrites beneath the bay.

COPENHAGEN (1934) was the first who brought to the fore, that the sulphur compounds of the so-called azoic region are not derived from the land. According to this author the H_2S is formed by reduction of sulphates present in the watery sediment under influence of anaerobic bacteria. Periodically, i.e., in the summer months gas would escape in great quantity and would cause a mass mortality of fish.

That the H_2S of the azoic region has not been transported there by rivers, viz., that it does not originate from the sulphur compounds of the land, but that it results from the reduction of sulphates of the sea water, is certainly correct. However, I cannot agree with the supposition, that H_2S is the cause of the mortality. In my opinion the mortality is caused by noxiousness of red water of dinoflagellates; the occurrence of red water in its turn being the result of the presence of upwelling water. On account of this upwelling nutrients are available nearly all the year round in a high concentration. As a result the production of zoo/phytoplankton is excessively great. In this very eutrophic surroundings at certain times of the year a "waterbloom" occurs of some elements of the phytoplankton. MARCHAND after defending the Kuiseb underground water hypothesis adds at the end of his paper, that during occurrences of mortality the water along this area of the coast is of a blood red colour: "Now, some writers have suggested that this is also due to the flood waters from the rivers. Such, however, is not the case, for I have seen this red water and have taken some of it and examined it under the microscope when the red colour is revealed to be due to masses of a species of phosphorescent organism, viz., *Noctiluca*. Such red water occurrences are quite common on the South African Coast. "Dark water", due to masses of diatoms in the sea is also seen quite often on this part of the West Coast and I would suggest here, that sometimes minor occurrences of fish mortality are due not to the setting free of noxious compounds and gases from the bottom, but to vegetable decay of these masses of *Noctiluca* and diatoms polluting the water." (MARCHAND, 1928, p. 3).

I do not agree with MARCHAND in the following respects: In the first place not minor, but *all* periodical occurring mass mortalities in this region are caused by noxiousness of the plankton. Secondly in MARCHAND's opinion the noxious effect is pollution of the water by a great mass of dead plankton; it being indifferent if dinoflagellates are present or a mass of other dead phytoplankton organisms, e.g., diatoms. However, the mortality occurs only during occurrences of red water, and, therefore, only red water organisms are responsible.

Dinoflagellates are lovers of warmth; therefore, a mass development of dinoflagellates, and with that great outbreaks of red water will occur especially in that time of the year, when the temperature of the surface water is relatively high. The highest temperatures are to be met with in the southern summer. This is in my opinion the explanation of the fact, that the mortalities, as they are caused by great outbreaks of red water, always occur in the southern summer.

The above mentioned hypothesis has to be justified by researches in loco; this being impossible during the war, I searched for another proof, which I found by raising the following question: If in the Walvis Bay region upwelling water is the cause of the occurrence of red water and in its turn red water causes mass mortality of fish, does one find in other regions of upwelling water fish mortality caused by red water too? To answer this question I made a study of the literature on cases of mass mortality of fish (and also of invertebrates); the answer proved to be in the affirmative (BRONGERSMA, 1943; 1944; 1947). In the literature on dinoflagellates the trio upwelling water — red water — mass mortality appeared to be known already from the Californian region. However, as far as I am aware, the question whether they occur in other regions of upwelling water too, has never been put forward. In those regions of upwelling, where the phenomenon is very intense (South West Africa; Peru-Chile) red water and mass mortality occur very often; near Walvis Bay sometimes 4 or 5 times a season. In other regions of upwelling (for instance near the coast of California) these phenomena occur on rare occasions only (ALLEN, 1941).

From the above mentioned it is obvious, that there are certain regions (those peculiar regions of upwelling water), where red water and mass mortality of fish (and invertebrates) take place periodically or episodically on account of similar causes. Such regions undoubtedly have existed in the geological past too.

As has been emphasized by BRONGERSMA (1944; 1947) in certain parts of regions of upwelling the quantity of organic material reaching the sea bottom is so enormous, that anaerobic conditions originate and as a result a rather great part of it does not get oxidized [1]). This is the result of various factors: of the enormous great year production of the plankton in regions of upwelling, of the phenomena of red water and mass mortality, etc. Not only the high organic content, but all the above mentioned peculiarities of the azoic region near Walvis Bay are in last instance caused by upwelling water (for the argumentation see BRONGERSMA, 1947). It will be obvious that if these peculiarities occur combined in a fossil deposit, the chance is rather great, that this sediment originated in a region of upwelling water too. In this respect it is noteworthy, that the sediment of the azoic

1) The possibility is not excluded that the peculiar sediment found by the John Murray expedition in the vicinity of Cape El Hadd, S.E. Arabia (SEYMOUR SEWELL, 1934; 1935; STUBBINGS, 1939; WISEMAN & BENNETT, 1940) owes its origin to the presence of upwelling water too.

region shows a remarkable resemblance with certain bituminous fish shales; the similarity being particularly striking with those shales that consist for a considerable part of the siliceous remains of fossil diatoms (Californian miocene Monterey shales; oligocene menelite shales of the Carpathians, etc.). These shales are considered by most oil geologists as source beds of petroleum.

To decide if the sediment of the azoic region near Walvis Bay is of importance with regard to oil geology, it must be settled if this sediment is gyttja or sapropelium. The presence of H_2S in a sediment is certainly no proof that it is sapropelium, for in the deeper layers of gyttja H_2S occurs just as well. The point is where the boundary O_2/H_2S is to be met with. It seems probable that in the sediment of the azoic region the boundary lies nearly at the surface of the sediment, whereas in certain times of the year (during heavy outbreaks of red water) it lies in the free water. A sharp boundary between gyttja and sapropelium probably does not always exist in nature. There will be transitional stages, one being nearer to gyttja, the other to sapropelium. In any case the sediment of the azoic region is not a typical gyttja; a character of the latter being the presence of benthonical invertebrates. As the latter are very scarce in this region a great part of the sediment will be converted by bacterial action only. It seems probable that the sediment of the azoic region, at least parts of it, approach to a true sapropelium. Most oil geologists are nowadays of the opinion that a marine sapropelium may originate only by stagnation of the lower water layers. If, however, the sediment of the azoic region by a further analysis (exact determination of the boundary O_2/H_2S; labile organic compounds preserved?) appears to be (near to) a sapropelium indeed, proof is furnished that a sapropelium of considerable extent may originate in the open sea without any water stagnation.

According to MARCHAND (l.c.) fish remains are very numerous in the sediment of the azoic region; when trawling in this zone fish bones are brought up by the bucketful. "The area seems to be a burialground for fish." In recent marine sediments remains of fish are usually very scarce or absent. Otoliths and isolated teeth are the only fish remains, that occur rather frequently, but the softer bones like the vertebrae and the ribs are very scarce. There are, however, fossil deposits in which fish remains occur in great quantity. SMIRNOW (1930) in dealing with the oligocene of the northern Caucasus speaks of a churchyard of fish. Besides isolated parts of fish often nearly complete skeletons are to be met with. Because such deposits were formed in the geological past, it is worth while to search for an analogon in recent time. It is, therefore, desirable to study those rare sediments in which fish remains occur in a comparatively great quantity.

For a fossilisation of vertebrates a very quick embedding after death is a first requirement. The latter is possible in two ways: either a rather thick layer of sediment is deposited directly after the death of the fish (for instance if the cause of death is a volcanic one), or the fish sinks on, and

partly or wholly sinks away in a soft sediment, in which anaerobic conditions prevail. Therefore, it seems probable, that part of the fish perished by the mass mortalities, at least as far as they sink down on the peculiar sediment of the azoic region, have a good chance to fossilize. As it has turned out by the present research that the mass mortalities as well as the peculiar sediment are caused by the presence of upwelling water, these regions are probably of importance to vertebrate paleontology. With regard to the possibility that in the sediment of the azoic region fossils occur in statu nascendi, it is desirable to study if fish remains occur in the deeper layers of the sediment and in what state of preservation.

The records of red water and mass mortality of all parts of the world summarized in BRONGERSMA (1947) will make it obvious, that it is not a mere hypothesis but a well established fact, that red water of dinoflagellates may cause mass mortality among fish and invertebrates. Opinions differ, however, greatly as to the question, how the mortality is brought about. The supposition is made by some authors, that the death of fishes and invertebrates is caused by the accumulation of toxic substances in the sea water following the decay of large quantities of plankton. A second hypothesis is, that the myriads of dinoflagellates cause asphyxiation by clogging the gills. In view of recent researches on paralytic shellfish poisoning, by which it is shown, that a powerful toxin may be produced by the living dinoflagellate plankton, this assumption probably has to be revised.

Paralytic poisoning of men by eating mussels is rather rare in Europe. On the Pacific coast of North America (upwelling water!) shellfish poisoning is a rather common occurring phenomenon. By research work started in California in 1927 it has turned out, that the agent responsible for the toxicity of the mussels is contained in the ocean water and approaches the shellfish beds more or less periodically (that is in the summer months) from offshore. There appears to be a close relation between the number of certain dinoflagellates and the poisonousness of the mussels, the annual maxima of certain species of *Gonyaulax* appearing to occur preceding and during each poison period. In 1933 the poison was isolated directly from dinoflagellate plankton.

Shellfish themselves appear to be resistant to comparatively large quantities of the poison; the same applies to other cold blooded invertebrates and vertebrates. Although the resistance of cold blooded animals is much higher, it still seems very probable, that paralytic shellfish poison or a related poison produced in the living dinoflagellate plankton is the cause of the mass mortality of fishes and invertebrates occurring periodically or episodically in various parts of the world. This conception is advocated already by SOMMER et al. (1937) with regard to the mortality of marine animals during the San Diego occurrences of red water: "Quantities of shellfish poison much larger than have been measured in the San Francisco region, quite possibly existed in the living plankton at that time, but since tests for toxin were not made this cannot be checked. Perhaps if the numbers of *Gonyaulax catenella* and related species associated with it during the present investigation had been greater, the quantities of poison extracted from the digestive glands of the mussels might have been many times larger than the tests have indicated, and the poison, possibly of sufficient potency to have caused either metabolic disturbances in the mussels or their death."

Along the coast of California red water and mass mortality occur on rare occasions only. Outbreaks of red water are very rare (1901, 1907, 1917, 1924, 1933, 1938, 1939); whereas an attending mortality is even more rare. Therefore, it may last many years, before the hypothesis, that the mortality is brought about indeed by a poison related to paralytic shellfish poison, can be tested. In the Walvis Bay region, however, mortality occurs nearly annually. Therefore, this is the obvious place to test the above mentioned hypothesis.

The war now being over oceanographical research can be started again; and, therefore, it is possible to justify the above mentioned hypotheses by researches in loco.

Summarizing the following studies have to be made:

A. *Red water and mass mortality.* A qualitative and quantitative study of the plankton all the year round. What dinoflagellates except *Noctiluca* may be responsible for outbreaks of red water along this coast? What species of dinoflagellates may be responsible for mortality? As mortality occurs only during heavy outbreaks of red water the following must be studied: What is the extent of the red water and what is the number of dinoflagellates per litre during outbreaks being heavy enough to cause mortality? What oceanographical peculiarities (a high temperature being the result of a decrease of the upwelling?) coincide with the occurrence of red water? What oceanographical peculiarities are present in years of abnormal great outbreaks of red water and with that in the years of abnormal great mortality? Does the region of the most frequent occurrence of red water coincide with the azoic region?

B. *Sediment.* A further analysis of the sediment of the azoic region. Which of both is this sediment, gyttja or sapropelium? Labile organic compounds preserved? Cu, Ni, Va or Mo perhaps present? Does the boundary O_2/H_2S lie at some distance under the surface of the sediment or is H_2S present up to the very surface? Determination of organic carbon and nitrogen from the top layer as well as from layers at a depth of some dm under the surface.

C. *Poison.* Is the fish mortality brought about by a poison related to paralytic shellfish poison, the latter being produced by the living dinoflagellates during occurrences of red water?

Does paralytic poisoning of man by eating mussels in the southern summer occur on this coast?

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