The conclusions to be drawn from the foregoing analyses may be summarized briefly as follows:

(1) Periodogram analyses performed on oceanic wave records do not appear to give correct geophysical information. The numerous wave periods, and bands of periods, indicated by this type of analysis do not necessarily possess physical significance.

(2) Application of the hypothesis of generalized harmonic analyses to western North Atlantic wave records indicates that ocean wave patterns are not complex interference patterns resulting from combinations of many wave frequencies, but frequently consist of a single sinusoidal wave on which is superimposed an oscillatory component.

(3) The cyclical component appears to be that generated under the influence of a dominating oceanic meteorological situation, and the oscillatory component by local winds and other local disturbances tending to change the basic ocean wave pattern.

(4) Separation of the cyclical and oscillatory components and determination of their physical properties is possible by generalized harmonic analysis of finite portions of the primary data.

(5) In the case of Record 53-X, the wave pattern is indicated to be composed of a cyclical and an oscillatory component. The former proceeds throughout the data in regular sinusoidal fashion with an amplitude of 0.54 ft and accounts for approximately 64 percent of the variability in the wave pattern. The oscillatory component, with a theoretical amplitude of 0.67 ft is autoregressive, and strongly damped.

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Comparative Electron and Light Microscopic Investigations of Tactoid Structures in V_2O_5-sols

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THE SPINDLE-SHAPED TACTOIDS in Fig. 1, whose biological interest was recognized at an early date (*2*), have been investigated repeatedly with the polarizing microscope (*15*) and by X-rays (*1*). Electron microscopy has not been applied extensively to tactoids, although it has been used by various authors to study aqueous dispersions of tobacco mosaic virus (*10*) and of V_2O_5 (*3*), in both of which tactoids do form under suitable conditions.

In this investigation we studied the development and transformations with time of tactoid structures in a 2% V_2O_5-sol prepared according to the recipe of Zocher and Jacobsohn (*15*). Immediately after preparation a solution of this concentration shows a fine particle dispersion in the electron microscope, without structure or apparent orientation (Fig. 2). These colloidal particles have a mean diameter less than 50 A. In the polarizing microscope a solution of this concentration is optically empty.

In a liquid medium, structures of low rigidity are liable to deform and alter during the drying of speci-

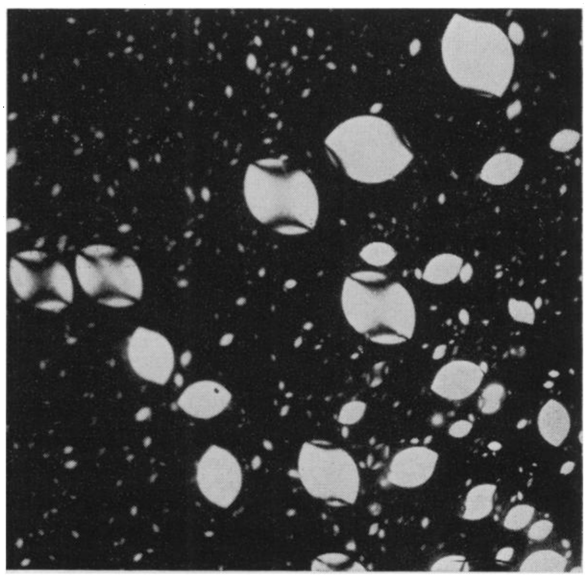


FIG. 1. Photomicrograph between crossed nicols of V_2O_5 tactoids, × 100.

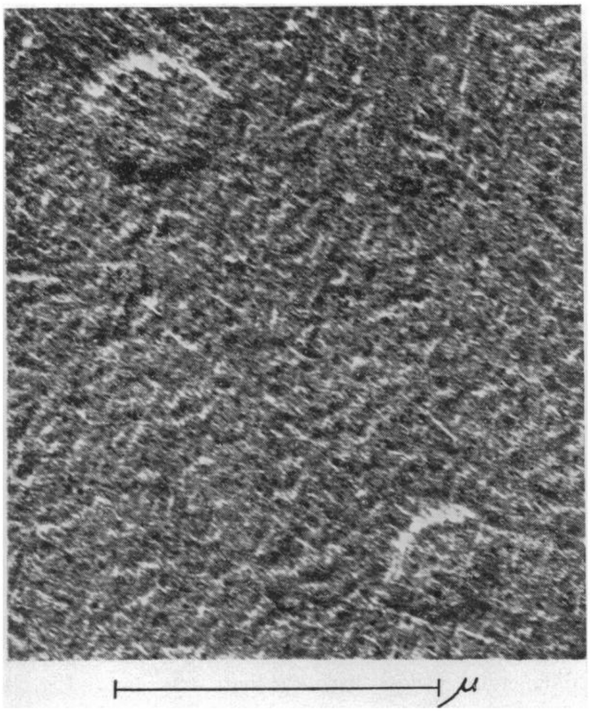


FIG. 2. Electron micrograph of a shadow-cast specimen of a three-hour sample of V_2O_5, showing fine particulate material, ×42,500.

mens preliminary to electron microscopy, so that structural details can be produced which are absent in the original specimen. In the present work with V_2O_5-sols an entire droplet of specimen apparently acquires the consistency of a gel at some period prior to complete drying. This is true only of the older samples, however, and not at all of the freshly prepared ones. As long as one is aware of the possibility of drying artifacts, as well as of other inherent characteristics of electron microscopy techniques, pseudostructures are not a serious drawback but may have real value and give much additional information. In order to get a more complete conception of the properties of a material, the electron microscope should be used in conjunction with other instruments. In the present work, because of the orientation which exists in the materials, the polarizing microscope has been chosen as a second instrument to aid in interpretation. The polarizing light microscope in many cases defines the spatial arrangement of structural elements, although these elements may have dimensions far below the resolving power of the microscope itself.

Electron micrographs of a dried 24-hour specimen show up the presence of tactoids (Figs. 3 and 4). Shadow-casting at very acute angles and stereoscopic electron microscopy reveal that the dried tactoids have exceedingly little thickness and are almost in the same plane as the film and the background gel throughout. In drying, the spindle-shaped bundle of rods collapses upon itself but retains the general outline of the tactoid. At this and at later stages, sheaves of rods also appear. With the polarizing microscope, solutions are observed to develop individual tactoids with time and complex, anisotropic structures after the aged solution has separated extensively into a lower gel-phase (tactophase) and a supernatant sol-phase (actophase) (*15*). The primary and probably significant variable during this aging process is the increase in size of the individual V_2O_5 crystals (flat orthorhombic rods) which form the elements of all anisotropic structures. This steady increase in size follows not only from electron microscopy evidence but also from a continuous increase with time of both

FIG. 3. Electron micrograph of a 24-hour sample of V_2O_5, showing positive tactoids. ×5,000.

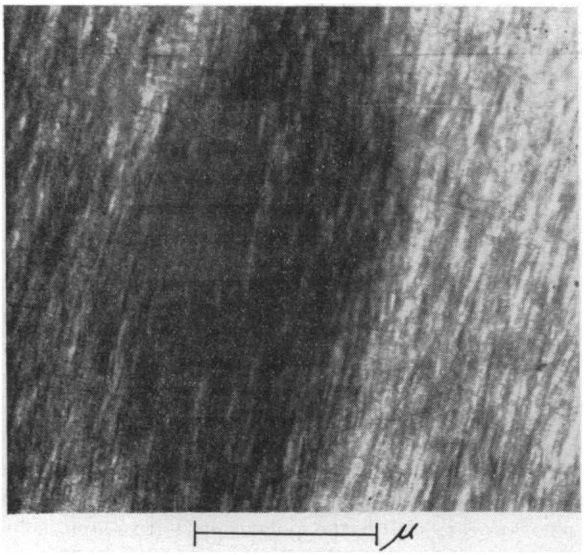


FIG. 4. Electron micrograph of a specimen of a 24-hour sample of V_2O_5 tactoid, taken at higher magnification to show directly the structure of and orientation within a dried, positive tactoid, × 24,000.

magnetic and streaming double refraction in dilute solutions free from structures (*6*), and from thorough X-ray optical investigations (*8*), pertinent results of which are summarized in Table 1.

TABLE 1

DIMENSIONS OF V_2O_5 CRYSTALS IN COLLOIDAL SOLUTION*

Age of V_2O_5-sol	c	b	a
	(in Angstrom units)		
Fresh	50	10	10
2 weeks old	150	20	10
20 years old	1000	100	30

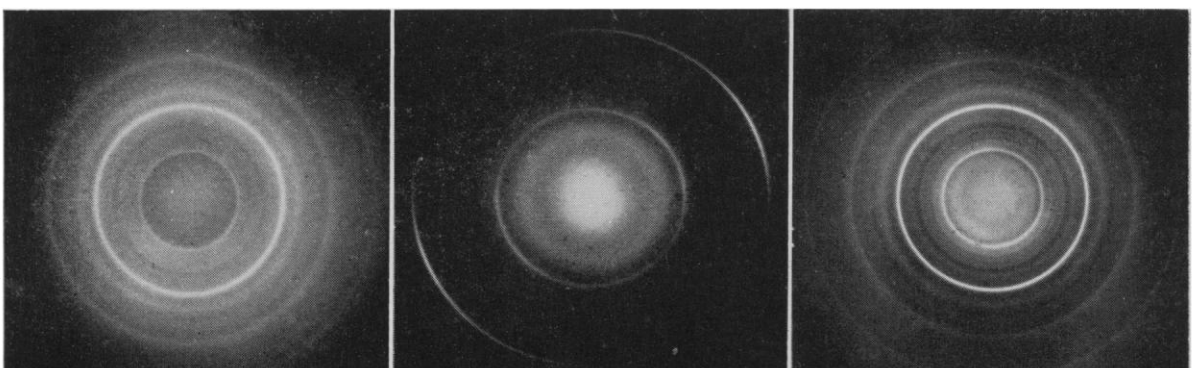
* Results by Ketelaar (*8*).

The electron diffraction patterns in Fig. 5 verify the crystalline growth for the solutions considered here. The patterns taken over the growth interval are characteristic of V_2O_5 in all cases: bright but broad lines from the early, particulate material (Fig. 5A), an oriented fiber pattern from the 24-hour specimen (Fig. 5B), and sharp, bright lines from a six-day specimen (Fig. 5C). The decrease in line broadening is very pronounced over this short interval.

The quantitative change in chromatic polarization from the center towards the periphery of the original tactoids, observed with the aid of auxiliary double refraction, proves that they are prolate spheroids prior to being dried out. What the electron microscope shows, therefore, is tactoids which have collapsed onto the supporting film, under maintenance of the nematic symmetry of orientation of the tactoid elements (Fig. 4). This drastic reduction in the thickness of tactoids during drying is proof, in addition to ultramicroscopic (*15*) and interference optical (*4*) evidence available, that the mutually oriented elements of tactoids maintain remarkably large, long-range equilibrium distances in the aqueous medium. A preservation of the mutual orientation in dried specimens is also indicated by the fact that electron diffraction yields distinct fiber diagrams. Fig. 4 shows the orientation of rods with their long axis parallel to the long axis of the spindle and the preservation of this orientation.

Fig. 3 and particularly Fig. 4 show variations in density across the images of dried tactoids which may be due to local coagulation of the rods into larger bundles while the tactoid is drying. On the other hand, ultramicroscopy and particularly X-ray analysis have indicated that the internal density of the original spindle-shaped tactoids is fairly uniform.

Occasionally sheaves of rods are found in electron micrographs of the dried specimens along with or instead of the tactoids. Apparently connected with this is the frequently stratified aspect of the back-



A B C

FIG 5. Electron diffraction patterns of V_2O_5: A—three-hour specimen, diffuse, broad lines; B—24-hour specimen, preferred orientation; and C—six-day sample, sharp crystal reflections.

FIG. 6. Electron micrograph of a 72-hour specimen of V_2O_5, showing negative tactoids, ×28,000.

ground which can be recognized in Fig. 2 despite the low magnification used. Such sheaves are observed also in electron micrographs obtained from the fresh juice of tobacco plants infected with tobacco mosaic virus (*7, 13*). The polarizing microscope has shown corresponding structures in original undried specimens only if typical tactoids fail to develop. Such sheaves of tactosol do not have a well-defined boundary towards the atactosol, but they generally extend over areas at least the order of magnitude of normal tactoids. These sheaves may be structural intermediates between typical tactoids and the structures to be discussed presently.

TABLE 2

AXIAL RATIOS OF POSITIVE AND NEGATIVE TACTOIDS (From electron micrographs)

Type	Number measured	Range of the major axis in microns	a/b
Positive	27	2.2 to 14.0	5.91 to 2.75
Negative	6	0.2 to 0.6	4.0 to 1.6

Wyckoff (*14*), working with purified tobacco mosaic virus protein, shows gold shadow-cast electron micrographs of frozen-dried specimens in which sheaf formation and stratified background are indicated somewhat similarly. The meshes observed in frozen, dried preparations were interpreted as negative tactoids (see below); but discrete, positive tactoids, which are illustrated in the present work, were not observed.

Forty-eight hours after preparation extensive anisotropic regions of tactosol are observed in the light microscope, interspersed with elliptical holes filled with atactosol. These holes, first observed by Zocher and Jacobsohn and named "negative" tactoids (*1*) are preserved during drying of the specimens (Fig. 6). The range of their axial ratios is similar to but less than that of the "positive" tactoids as shown in Table 2.

Prior to drying, these anisotropic structures are characterized under the polarizing microscope by a parallel orientation of the individual crystals with respect to the differential symmetry axis of the volume element. In contradistinction to a positive tactoid, there is no symmetry axis for the entire structure. Instead, the differential symmetry axis curves or suddenly changes direction. Except for minor artifacts and structural distortions, the electron micrograph is in agreement with the evidence obtained from double refraction. The electron micrograph clearly shows a transition of the tactosol towards a curving and occasionally interlacing fibrous structure. At the higher magnification of ×120,000 it is found that the individual fibers have a width of 65 A or less. Such fiber structures of V_2O_5 exhibit a positive double refraction, and since the individual crystals also exhibit this, it follows that the fibers must have a nematic structure.

This trend towards a fibrous structure is accentuated with further aging, as is shown in electron micro-

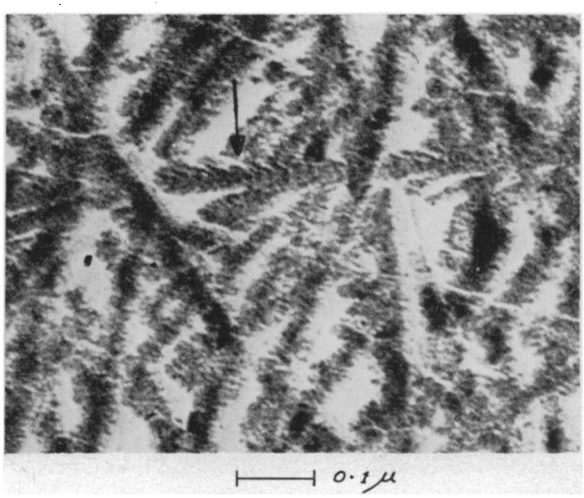


FIG. 7. Electron micrograph of a shadow-cast, 30-day sample, which shows the transverse structure in the rod-like crystals, ×120,000.

graphs obtained from the tactophase after aging for 30 days (Fig. 7). The equivalent in the polarizing microscope is a mosaic pattern of birefringent areas whose size is below the resolving power of the microscope. The electron micrographs agree with this basic type of structure in the sol.

As to the other interesting details brought out with high magnification and shadow casting in Fig. 7, it is not possible at the present time to decide whether these are characteristic for the dried specimens alone or also for the originals. The outstanding characteristic of these details is a transverse structure, particularly at the arrow. In the shadowgram this structure is repeating, with ridges 65 A wide and intervening valleys 35 A wide. Perpendicular to these dimensions, the average width of the fibers themselves is 300–400 A. The width of the ridges is compatible with the length to be expected from the data in Table 1 for the individual V_2O_5 crystals in sols of this age. On this hypothesis, each ridge defines an array of crystalline particles oriented parallel to each other and also, though with considerable less regularity, parallel to the fiber axis. An orientation of the crystal rods perpendicular to the fiber axis, assuming that the rods have a length of 300–400 A, is less likely but is not to be excluded. The possibility that the fine structure of Fig. 7 may not be representative of the original structures in the liquid medium imposes even more reservations upon a tempting further comparison between this transverse structure and the fine structure of collagen fibers, shown by electronmicroscope (*9*).

A freshly prepared solution of V_2O_5 is known to exhibit Newtonian flow. On aging, anomalous (elastic) flow is observed. Finally, the tactophase acquires the typical consistency of a gel-phase. These rheological changes, which accompany and are the result of the development and subsequent transformation of the anisotropic structures discussed, add further support to the concept that tactoids (geloids) may be the primary elements responsible for gel formation, at least in those systems where no chemical cross-linking occurs (*5*).

In conclusion, it is worth pointing out that no effects of electron bombardment upon any of these specimens were noted even under a biased gun at high intensity. This contrasts with the observations published earlier concerning the effects of electron bombardment upon "young" elliptical particles which form the elements of smectic tactoids of WO_3 (*12*), and also removes any possibility that the structures reported here are pseudostructures introduced by electron bombardment (*11*).

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