Geol. Jb.	**D 65**	5–23	4 Fig.	2 Tab.	2 Plat.	Hannover 1984

Outline of SONNE Cruise SO-17 on the Chatham Rise Phosphorite Deposits East of New Zealand

ULRICH VON RAD

Phosphorite nodule, prospecting, distribution, geophysical methods, geological methods, sampling, oceanography, expedition (Sonne SO-17), cruise outline, current measurements, S. Pacific (Chatham Rise), New Zealand

Abstract: The Chatham Rise phosphorite is a loose nodular gravel intermixed with glauconitic sandy muds in 400 m water depth on Oligocene chalk. The horizontal and vertical distribution of the phosphorite nodules which may be an important raw material for New Zealand's fertilizer industry was studied during a joint German/New Zealand cruise with R/V SONNE (March–May 1981). We used high-resolution profiling (3.5 kHz sonar, HUNTEC deeptow boomer), side-scan sonar, underwater television and photography and a large pneumatic grab sampler recovering 0.8 m^3 of sediment, mainly in four special study areas on the central Chatham Rise with acoustic transponder navigation. Direct current measurements and meteorological observations (wind, waves, swell) were also made for mining feasibility studies.

All grab samples were immediately processed onboard and the phosphorite coverage calculated and plotted. In the most promising areas, which are characterized on the boomer profiles by a bottom reflector with overlapping hyperbolae, the mean phosphorite concentration varies between 10 and 17% of the total sediment weight or approximately 54 kg/m^2. The overall patchiness of the phosphorite-rich areas, however, complicates the assessment of reserves.

[Abriß der SONNE-Fahrt SO-17 zu den Phosphoriten des Chatham-Rückens östlich von Neuseeland]

Kurzfassung: Auf dem Chatham-Rücken liegen in 400 m Wassertiefe Phosphoritknollen in einer Matrix von Glaukonit-Feinsand auf oligozänem Kreidekalk. Die horizontale und vertikale Verteilung der für Neuseelands Düngemittelindustrie interessanten Phosphoritvorkommen wurde 1981 in einer deutsch-neuseeländischen Prospektionskampagne mit F/S SONNE untersucht. Dabei wurden hochauflösende seismische Systeme (3,5 kHz Sonar, HUNTEC Deeptow Boomer), Side-Scan Sonar, Unterwasserfernsehen und -photographie und ein pneumatisch schließender Großgreifer, der bis 0,8 m^3 Sediment fördern kann, eingesetzt. Im wesentlichen wurden vier Detailarbeitsgebiete im zentralen Rückenbereich mit Hilfe Unterwasser-Transponder-Navigation untersucht. Direkte Strömungsmessungen und meteorologische Beobachtungen über Wind, Wellen und Dünung erbrachten Basisdaten für den eventuellen industriellen Abbau der Knollen.

Alle Greiferproben wurden sofort an Bord bearbeitet und die Phosphoritbelegung berechnet. Die phosphorithöffigsten Teilgebiete, die auf den Boomerprofilen durch einen Bodenreflektor mit sich überlappenden Diffraktionshyperbeln gekennzeichnet sind, enthalten etwa 10–17% Phosphorit im Gesamtsediment, was etwa 54 kg/m^2 entspricht. Die generelle Fleckenhaftigkeit der Phosphoritvorkommen kompliziert jedoch eine Abschätzung der Gesamtvorräte.

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[Очерк рейса 17 и. с. SONNE к фосфоритам Чатамского хребта восточнее Новой Зеландии]

Резюме: На Чатамском хребте на глубине воды 400 м залегают фосфоритовые конкреции в основной массе глауконитового тонкого песка на олигоценовом мелу (chalk). Горизонтальное и вертикальное распределения фосфоритовых месторождений, представляющих интерес для промышленности удобрения Новой Зеландии, исследовались в 1981 г. с и. с. SONNE в немецко-новозеландской разведочной кампании. При этом применились сейсмические системы высокого разрешения (3,5 kHz Sonar, HUNTEC Deeptow Boomer), Side-Scan Sonar, подводные телевизия и фотография, а также крупный пневматический грейфер, добывающий до 0,8 м^3 осадков. Исследовались в существенном 4 детальные рабочие области в центральном хребте при помощи подводной навигации посредством Transponder. Прямые измерения течения и метеорологические наблюдения за ветром, волнами и зыбью дали базисные данные для эвентуальной промышленной разработки конкреций. Все грейферные пробы были обработаны немедленно на борту, а вычислена фосфоритовое перекрытие. Самые перспективные в отношении фосфоритов частные области, охарактеризованные на разрезах Boomer почвенным отражателем с перекрывающимися диффракционными гиперболами, содержат около 10—17 % фосфоритов во всеобщем осадке, что соответствует около 54 кг/м^2. Нерегулярное распределение фосфоритовых месторождений, однако, осложняет оценку всеобщих запасов.

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1. Background and Objectives

The Chatham Rise is a 150 km wide and 1000 km long microcontinent which is submerged to a water depth of about 400 m and extends from the South Island of New Zealand in the west to the Chatham Islands in the east (Fig. 1).

Phosporite gravel intermixed on the sea floor with glauconitic foraminiferal muddy sand was first reported in 1952 (REED & HORNIBROOK 1952) and investigated in more detail by NORRIS (1964). A commercial reconnaissance survey in 1967/68 (GLOBAL MARINE INC. unpublished reports; PASHO 1976) identified the area between 179° E and 180° as the most promising site for exploitation.

In 1975, the New Zealand Department of Scientific and Industrial Research (DSIR) decided to commence a detailed assessment of the geology and agronomic potential of the Chatham Rise phosphorite, in order to reduce New Zealand's dependance on the import of superphosphate fertilizer for its agriculturally-based economy. Between 1975 and 1978 the New Zealand Oceanographic Institute (NZOI) conducted four cruises to the central Chatham Rise to establish the age, distribution, petrology and geochemistry of the phosphorites (CULLEN & SINGLETON 1977, CULLEN 1978, CULLEN 1980).

In 1978, the Chatham Rise phosphorite investigation was taken a significant step forward with the initiation of a joint DSIR-Bundesministerium für Forschung und Technologie project involving the Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) and NZOI. Using sophisticated navigational techniques anboard the German R/V VALDIVIA, an intensive survey was accomplished in four weeks. The recovery of 687 sediment samples was used to study the quantitative distribution of nodules: reserves of 18 million tons of phosphorite nodules were indicated by geostatistical methods in an area of 284 km^2 with a high regional variability (KUDRASS & CULLEN 1982).

The encouraging results of this cruise were considered sufficiently interesting for a major New Zealand company (Fletcher-Challenge Ltd.) to apply for a prospection license to cover much of the Chatham Rise. Recent agronomic tests have demonstrated that Chatham Rise phosphorite forms a valuable direct-application phosphate fertilizer which performs agronomically at least as well, and in a number of respects better than superphosphate (GREGG et. al 1981). This stimulated BGR and NZOI to plan a second joint cruise of eight weeks duration with R/V SONNE using specially developed sampling and profiling equiment. This cruise which was to apply the VALDIVIA results to an expanded area with more sophisticated methods was planned and conducted with the full participation of New Zealand (Fletcher-Challenge Corporation) and German industrial partners (Preussag AG and Salzgitter AG). The main objectives of the SO-17-cruise were

(1) the regional distribution and quantitative assessment of the phosphorite reserves on the Chatham Rise;

(2) the investigation of the near-surface structure and stratigraphy; and

(3) the facies, age, and genesis of phosphorite nodules and associated sediments.

An important aspect of the cruise was to correlate different continuous methods, such as underwater television, side-scan sonar, 3.5 kHz sonar, and HUNTEC-deeptow boomer systems with the ground-truth of narrow-spaced, well-positioned grab samples, and to test the applicability of those tools for the prospection of phosphorites.

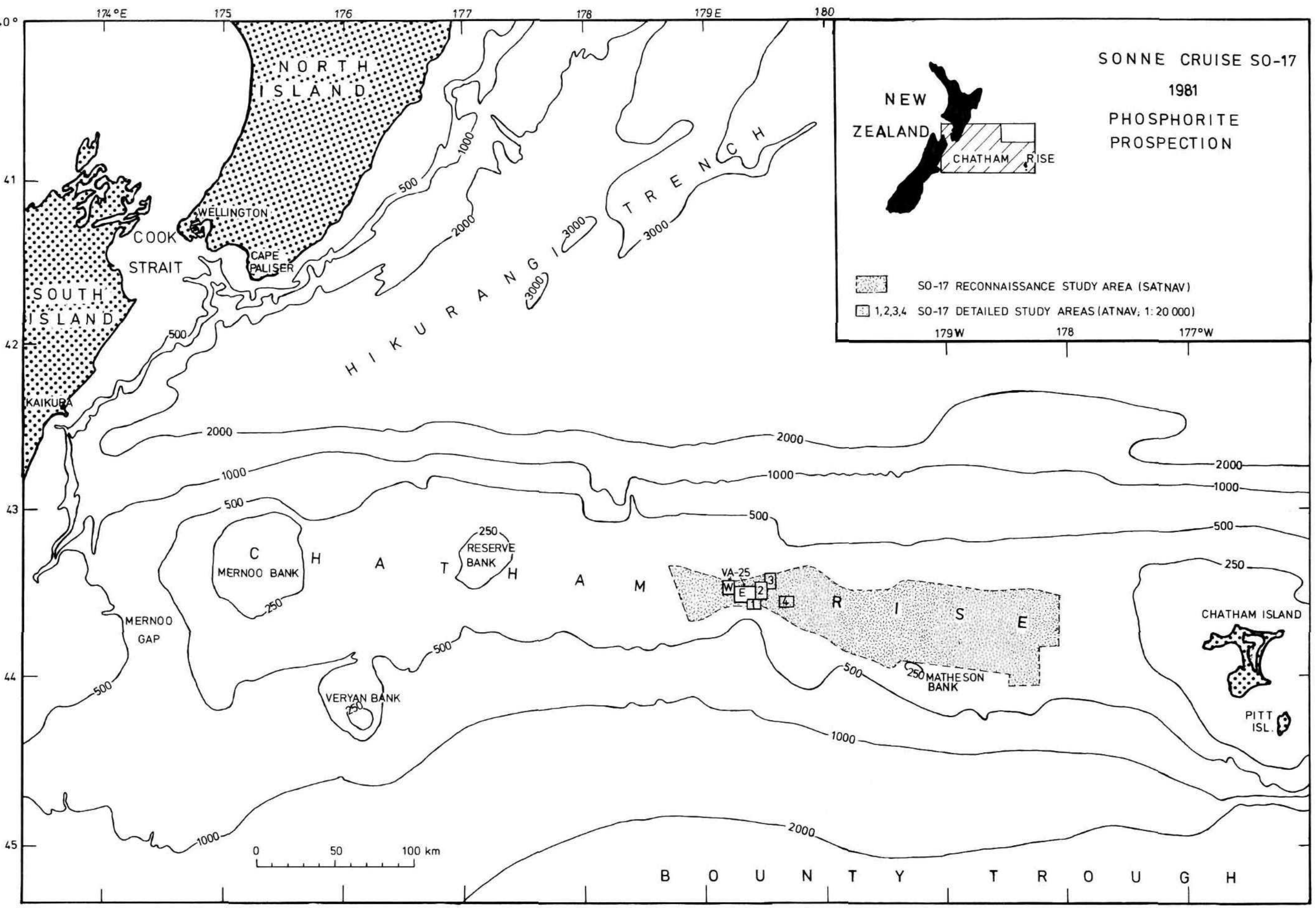

Fig. 1: Area of investigation, SO-17-cruise.

Table 1: Shipboard Scientific and Technical Staff

Name	Institution/ Company	Function	Leg
VON RAD, U.	BGR	chief scientist, geologist	A–C
ALLEN, R.	L&S	draftsman	A
BIKA, G.	HUNTEC	electronics technician	A–C
BLÜMEL, G.	BGR	geologist	C
BROWN, I.	NZMS	meteorologist	A
BURKHARDT, J.	PR	marine technical engineer	A–C
CULLEN, D.	NZOI	marine geologist	C
DAWSON, E.	NZOI	marine biologist	C
FALCONER, R.	FCL	geophysicist	A, C
GERLACH, Chr.	DST	geologist (bathymetry)	A–B
GOERGENS, R.	BGR	marine technician	B–C
GROTE, A.	DST	marine technician	A–C
HANSEN, D.	PR	geophysicist	A–C
HARONGA, Mrs. M.	L&S	draftswoman	C
HARRISON, G.	SID	photographer	B
HERBST, K.	PR	geophysicist	A–C
HULSE, Ms. C.	NZGS	laboratory technician	C
KAWOHL, H.	BGR	marine electr. technician	A–C
KNOPF, W.	PR	electronics technician	A–C
KUDRASS, H.-R.	BGR	marine geologist	B
MEYER, K.	PR	marine geologist	A–C
MITCHELL, J.	NZOI	marine/laboratory technician	A, C
NEWPORT, Mrs. H.	L&S	draftswoman	B
ORR, N.	NZGS	laboratory technician	B
RILEY, P.	FCL	soil mech. engineer	B
RÖSCH, H.	BGR	mineralogist	A–C
SCHOLZ, G.	DST	electronics technician	A–B
SILLARS, Ms. K.	T&I	laboratory technician	B
SMALE, D.	NZGS	geologist	C
TOAN, D. K.	FCL	soil mech. engineer	C
VERBURG, Chr.	SID	photographer	A
WATERHOUSE, B.	NZGS	geologist	A
WILLIAMS, R.	NZOI	laboratory technician	A
WOLTER, G.	BGR	ship's doctor	A–C

BGR = Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover
DST = Deutsche Schachtbau und Tiefbohrgesellschaft, Lingen (Salzgitter)
FCL = Consultants to Fletcher-Challenge Corporation Ltd. (Auckland)
L&S = Land and Survey (DSIR)
NZGS = New Zealand Geological Survey, Lower Hutt, Auckland, Christchurch (DSIR)
NZMS = New Zealand Meteorological Survey
NZOI = New Zealand Oceanographic Institute (DSIR)
PR = Preussag AG, Hannover
SID = Science and Information Department (DSIR)
T&I = Trade & Industries, Wellington

The following paper describes the program of the SONNE cruise SO-17 and the techniques used (Fig. 2). A short summary of the shipboard results is added, while the main results of the shipboard and shore-based studies, done in Germany and New Zealand, are reported in the following contributions (for a summary and synthesis of our results see KUDRASS & VON RAD (b) this vol.).

The SO-17-cruise was carried out under the auspices of the German-New Zealand Governmental Agreement on Scientific and Technological Cooperation and of a special agreement between DSIR and BGR on the data of this cruise. The R/V SONNE was chartered by BGR, and equipped by Preussag AG and BGR. The Federal Ministry of Research and Technology of the Federal Republic of Germany financed the major part of the cost for charter, equiment and personell. Also the New Zealand Department of Scientific and Industrial Research (DSIR) and Fletcher-Challenge Ltd. contributed funds and personell to the cruise (Table 1).

2. Cruise Schedule and Program

The strategy of the SO-17-cruise comprised

(1) the investigation of four special study areas (each with about 50–80 km^2) in which we laid out an array of 6–8 underwater acoustic transponders, in order to achieve optimum positioning for detailed bathymetric and high-resolution seismic surveys and narrow-spaced sampling; and

(2) on the other hand, the reconnaissance mapping of larger areas (about 14,000 km^2) by widely spaced profiles and samples which are based on satellite navigation, in order to get an overview of the structure and phosphorite prospectivity of larger areas between 178° E and 178° W.

The SO-17-cruise was subdivided in three legs, each of 16–20 days duration, which all started and ended in Wellington (N.Z.).

The first leg (SO-17A: March 30–April 15, 1981) was used for the testing of the newly developed or applied methods in Area 1 (64 km^2; with 8 acoustic transponders; see Fig. 1), directly adjacent to the eastern area investigated during the VALDIVIA-cruise.

During the second leg (SO-17B: April 17–May 7, 1981) we investigated Areas 2 (63 km^2) and 3 (36 km^2, Fig. 1) in detail and studied a larger area between 178° 50′ E and 179° E by profiling and extensive sampling.

During the third leg (SO-17C: May 9–27, 1981) we made a reconnaissance survey of a large (11,400 km^2), very poorly known area of the eastern Chatham Rise between 179° E and 178° W by profiling (boomer) and widely spaced sampling. Then we investigated Area 4 (80 km^2, Fig. 1) in detail by seismic profiling, photo surveys, and detailed grab sampling, especially within a 1×1 km test area.

3. Methods

The instrumentation used for high-resolution seismic profiling, sea floor surveying and bottom sampling is diagrammatically represented in Fig. 2.

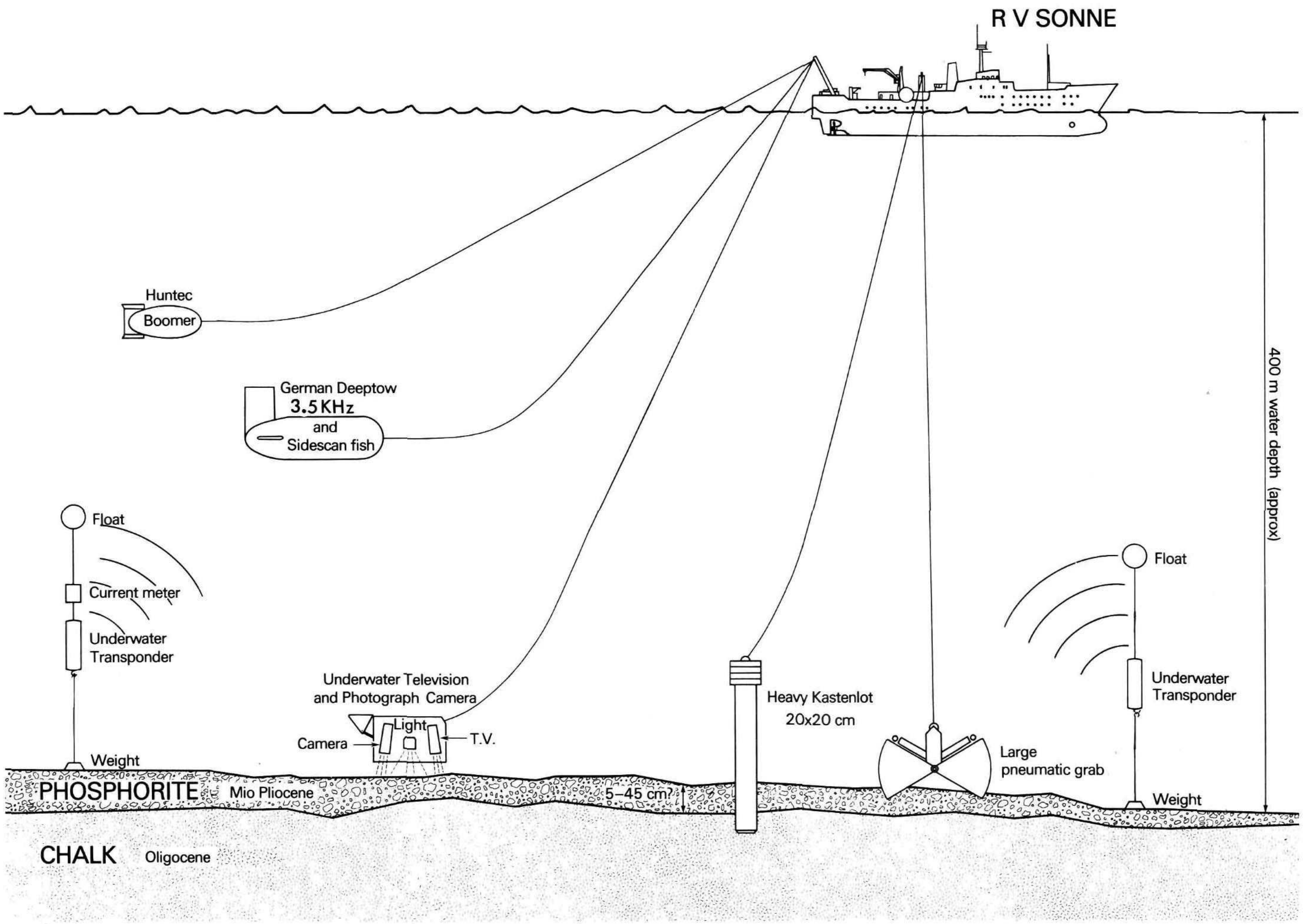

Fig. 2: Instrumentation, SO-17-cruise (scale of instruments not comparable).

3.1 Ship and Navigation

R/V SONNE is a research vessel specialized for geoscientific work (Plate 1; Fig. 1) with 2607 GRT, a length of 86.5 m, 14.2 m beam width, 6.5 m draught and a crew of 25 men.

SONNE is equipped with a MAGNAVOX satellite navigation system coupled to a doppler sonar to determine accurately the geographic position. After processing and correction of the navigation data by the Systems computer a positioning accuracy of 200–500 m (–1000 m) was reached.

A more precise determination of the ship's relative position was achieved by an underwater acoustic transponder navigation (ATNAV) system consisting of an array of 6–8 transponder laid 3000–4000 m apart on the sea floor. Under favourable conditions, a positioning (and relocating) accuracy of 30–50 m was reached with errors of up to 100 m near the margins of the ATNAV arrays. The geographical coordinates were determined by optimum adaptation of ATNAV positions and satellite fixes. With 10 satellite fixes available, the accuracy of latitude/longitude values within the ATNAV areas was about ± 180 m (0.1 n.m). For each detail area a set of maps in the scale of 1:20,000 was drawn on board and all profile data (bathymetric, HUNTEC boomer, Deeptow, TV profiles) and sampling stations recorded (KUDRASS this vol.: Fig. 3–6).

3.2 Bathymetry and Morphology

The bathymetric evaluation is based on the specially installed shallow-water echosounder ATLAS-DESO 20 (33 kHz, 16° angle, maximum water depth 1500 m). After installation of a wave compensation interface, the resolution was ± 20 cm. Already on board the bathymetry was mapped for Areas 1–4 (scale 1:20,000, 5 m isobaths) and for the reconnaissance area from 178° 30′ E to 178° W (1:100,000, 10 m isobaths).

Areas 1–4 are concentrated near latitude 179° 30′ E where the main E–W trend of Chatham Rise changes eastward to a NW–SE direction. The crest of the Chatham Rise (about 370–400 m waterdepth) is characterized by a very rough microrelief with maximum depth differences of 10–20 m and maximum angles of about 5° (KUDRASS & VON RAD (a) this vol.). Below a water depth of 400 m (Areas 2–4) or 425 m (Area 1), the relief is considerably smoother and the rise slopes to the flanks of the rise. For a detailed bathymetric map of the central Chatham Rise see CULLEN & MITCHELL (this vol: Plate 1 in backpocket).

3.3 Oceanography

3.3.1 Current Measurements

A knowledge of the surface and bottom currents can help to understand sediment distribution and bottom transport and will be required for the engineering of a mining device. Since no direct current measurements were made on the Chatham Rise previously, a modest current measuring program was undertaken (HEATH this vol.). One string ot three Aanderaa current meters was moored on the crest of the rise at 43° 34.4′ S, 179° 26.9′ E (water depth 410 m) from 20 April to 24 May 1981 (34 days). The individual meters were located at depths of 43, 193, and 393 m below the surface and recorded current speed and direction at 10 minute intervals. A first evaluation of the current speed and direction by Subsea Surveys (N.Z.) Ltd. (unpubl. Rep. for Fletcher-Challenge Ltd, 1981) showed that the current velocities measured at 17 m above the sea floor range from about 5–24.2 cm/sec (mean: 12.5 cm/sec), and are mainly SE directed (Fig. 3). These current speeds are well above

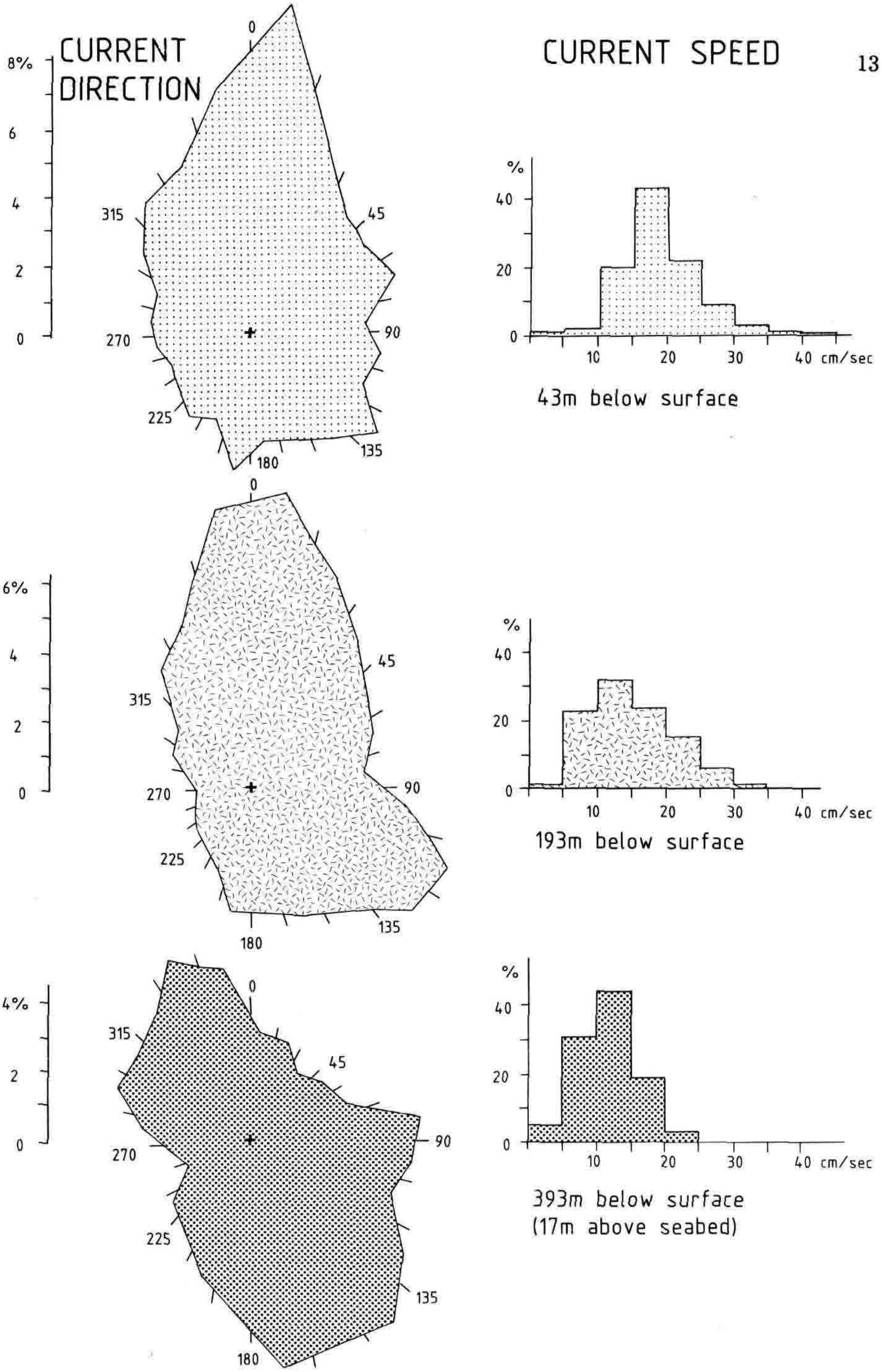

Fig. 3: Direction and speed of currents measured at 43° 34.3′ S/179° 26.9′ E on central Chatham Rise 43 m, 193 m, and 393 m below the surface (sea level). Distribution of current direction categorized in 15° sectors (0–15, 15–30°, etc.) in percent of total observations over 34 days (1 measurement/10 minute interval). Current speed is categorized in 5 cm/sec increments and is shown as frequency histogram in percent of total observations (1 measurement per 10 minute interval). Modified after Subsea surveys (NZ) Ltd (unpubl. Report for Fletcher-Challenge Ltd., September 1981).

the threshold to move silt and fine sand and able to explain the winnowing of the gravelly phosphorite-rich lag deposits on the central Chatham Rise. The measured surface currents are considerably faster (5–42.9 cm/sec, mean about 17.5 cm/sec) and mainly N-directed (with a minor SE-ward mode; Fig. 3). Spectral (tidal harmonic) analysis of the current meter records shows that the water movement is dominated by the semidiurnal and diurnal tides (HEATH in press).

3.3.2 Wave Measurements

Information on likely wave and swell conditions is required for mining feasibility studies. Because no direct measurements have been made on Chatham Rise before, Fletcher-Challenge Corporation began an investigation by contract with Subsea Surveys Ltd, using Datawell wave rider buoys with a vertical accelerimeter output. Two buoys were deployed, one in the SO-17 area (with data being transmitted to R/V SONNE), and one anchored 20 miles off the Chatham Islands and monitored on the islands. The preliminary results indicate that the "significant wave height" (the average height of the largest one third of the waves) measured during 10 days in April 1981 on the Chatham Rise Site ranges from 2–5.5 m with a mean between 3–3.5 m. At the Chatham Islands Site, the significant wave height measured over a 4-month period exceeded 2 m for 90 % of the time, 3 m for 45 %, 4 m for 20 % and 5 m for 5 % of the time. Wave steepness is high (1:20), a typical feature for southern hemisphere waves.

3.4 Meteorological Observations

During the first leg of the SO-17-cruise, the wind, sea and swell conditions were monitored by Dr. IAN P. BROWN (New Zealand Meteorological Service), in order to test and improve the accuracy of the weather forecasts of the National Weather Forecasting Center. During SO-17B and SO-17C wind speed and direction and all wave and swell data were monitored by the radio officer of R/V SONNE (H. STRATMANN). Measured wind speeds ranged from about 2–30 (maximum 44) knots. The main wind direction was from (180–)220–320(–360)°, a subordinate direction from 80–120(–180)°. Wave heights measured from 1–3 (maximum 4.5) m with periods of 1–4 (maximum 8) sec. The swell came usually from the W and SW (220–340°, "roaring westerly fourties").

3.5 Geophysical Methods

3.5.1 ORE Sediment Echograph

Since March 1981, R/V SONNE has a 3.5 kHz subbottom profiler with 16 ORE transducers mounted in the ship's hull (transmitting/receiving frequency 1–12 kHz, rate 125–1000 ms, puls length usually 0.2 ms). Despite a pulse rate of 0.2 ms, the resolution was only 3–4 m due to ringing. The HUNTEC Boomer gave a much better resolution in water depths between 300 and 1000 m. Beyond that water depth, the ORE Subbottom Profiler with its higher acoustic output and better signal-to-noise ratio is preferable.

3.5.2 HUNTEC Deeptow Seismic System

For high-resolution seismic profiling a boomer rented from HUNTEC Ltd. was towed with a speed of 3–6 knots at a water depth of 180–80 m (Plate 1, Fig. 2). The high energy (560 joules), high frequency of the seismic signal (1.4 kHz used during SO-17), the pressure pulse of 0.2 ms and the firing rate of about 120 shots per minute provided excellent detail of the sedimentary sequences. Down to a maximum water depth of 550 m we reached a resolution of about 0.3 m with a penetration of up to several decameters (HANSEN; FALCONER et al. this vol.). Below this water depth the comparatively high ship's noise impeded satisfactory results.

Altogether the boomer was used over a length of 2639 km, even at a sea state of 7. Later the tapes of some of the boomer records were processed by HUNTEC, in order to evaluate acoustic reflectivity properties (KUDRASS & VON RAD (a) this vol.).

3.5.3 Deeptow System (3.5 kHz, Side-scan Sonar)

A 100 kHz side-scan sonar mounted in a deep-tow fish was used to map the reflectivity and small-scale morphology of the sea floor (Plate 1, Fig. 3). The instrument was towed with a speed of about 2 knots, approximately 50 m above the sea floor, the position of the fish relative to the sea floor being indicated by a built-in 3.5 kHz subbottom profiler. A 200 m wide strip of sea floor on either side of the ship's track was scanned whithin which the distribution of phosphorite nodules and chalk exposures was delineated (KUDRASS & VON RAD (a) this vol.).

3.6 Geological Methods

3.6.1 Underwater Television and Photography

A small underwater photo and television sled was utilized ten times during the SO-17-cruise from the drifting ship (19 hours; 24 km). 350 color and 150 black-and-white photos were taken and the TV data recorded on 17 video tapes for further geological and biological analysis (see KUDRASS & VON RAD (a) and DAWSON this vol.).

3.6.2 Large Pneumatic Grab-Sampler

Most (532) sediment samples were recovered by a large (0.8 m^3) grab sampler which was specially developed for this cruise by Preussag AG and Peiner AG (Plate 2, Fig. 1). This grab sampler has a weight of 1.8 tons, and pneumatically closing and opening jaws, which are driven by compressed air (10 l, 20 bar; closing power: 1.5 t). Therefore the sampler usually penetrated the phosphorite-bearing glauconitic sand and sampled also the top of the underlying chalk. The maximum penetration was 50 cm, the maximum sediment recovery 1.3 t including 500 kg phosphorite. Down to a maximum water depth of 1000 m this sampler was very succesfull in obtaining nearly undisturbed samples, even in very phosphorite-rich pebbly sands and semiconsolidated chalk (we even got samples from large flint concretions and graywacke outcrops).

Fig. 4 shows the excellent characteristics of the large grab: even at phosphorite contents of 30–40 weight-%, the grab had a penetration of 50 cm; only extremely phosphorite-rich (40–60 %) samples reduced the penetration of the grab to <30 cm.

3.6.3 Vibrating Sieve Device

All grab samples containing phosphorite were washed on board using a specially developed large vibrating sieve device. This device consists of a hopper for the large grab and two vibrating sieves (8 mm, 1 mm) through which the samples were washed (Plate 2, Fig. 2).

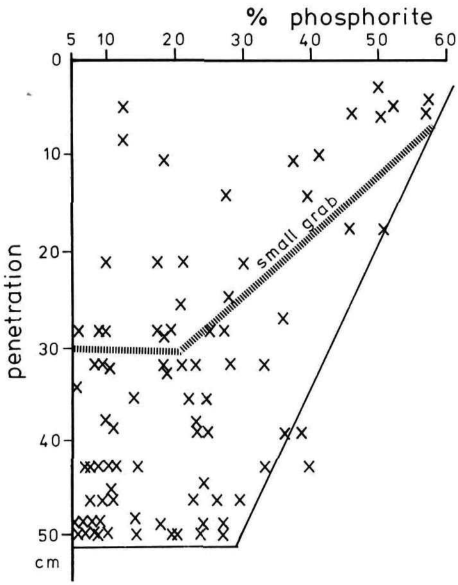

Fig. 4: Penetration of large pneumatic grab sampler versus phosphorite content. Only those SO-17-samples which did not reach the underlying chalk are plotted (×). Note the excellent penetration of the large grab in sediments with a phosphorite concentration up to 30 %, as compared to the small grab (used only during the VALDIVIA cruise), the values of which lie only above the dashed line.

3.6.4 Other Sampling Devices

A few times we used also a heavy kastenlot (25×25 cm box corer, 3 m long, weight 1.2 t), but did not succed in getting satisfactory penetration. A vibrocorer (Kieler Hammer, Hydrowerkstätten), specially adapted for water depths up to 440 m, was unfortunately lost during SO-17A. Two times we took piston cores (5 m), and three times the chain bag dredge was used to recover Mesozoic hard rocks.

3.7 Shipboard Laboratory Work

As mentioned above, all grab samples were immediately processed on board to provide a continuous assessment of the phosphorite concentration in the glauconite-foraminiferal sands. All phosphorite-bearing grab samples were washes, sieved, and the 1–8 mm and >8 mm fractions weighed, described and representative samples taken (VON RAD & RÖSCH this vol). The following quantitative data were recorded for each sample: penetration (cm), thickness of phosphorite-glauconite sand layer (cm), total weight of sample (kg), weight of phosphorite-glauconite sand without underlying chalk (kg); weight-% and phosphorite content of 1–8 mm and >8 mm fractions, maximum diameter of phosphorite nodules. From these values we calculated the phosphorite content (in weight-% of the total phosphorite-glauconite sand) and the phosphorite coverage (kg/m^2; KUDRASS this vol.). All these parameters were plotted on maps (1:20,000) for the four ATNAV areas. We also tested the mechanical properties of the phosphorites and the associated muddy glauconite sand and underlying calcareous ooze/chalk, in order to establish their density, water content, shear strength and plate-bearing capacity (MEYER & TOAN this vol.). These parameters are important for the design of any future mining device.

4. Outline of Shipboard Results

Since the final results of the shipboard and shore-based evaluations of the SO-17 data are presented in the following chapters, I will summarize here only some of the major shipboard results (see also Table 2).

Table 2: Overview of Shipboard Data

1. Seismic profiling and bottom observations

(a) HUNTEC deeptow boomer: 2639 km (318 h)
(b) German Deeptow (Sidescan): 176 km (3 deployments)
(c) Underwater TV/photo sled: 24.5 km (6 deployments)

2. Geological sampling

At 550 stations the following devices were used

(a) 532 × large pneumatic grab (total recovery: 500 t of sediment with about 42 t of phosphorite)
(b) 13 × heavy Kastenlot (box core) 6.1 m
(c) 2 × piston corer (5 m)
(d) 2 × vibrocorer (Kieler Hammer)
(e) 3 × chain bag dredge

3. Oceanographic and meteorological data

(a) Direct current measurements for 34 days (3 meters)
(b) Monitoring of signals from wave-rider buoy
(c) Continuous recording of data on wind, wave and swell conditions

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The structure and "seismic facies" of the uppermost 10–50 m of sediment were studied with high-resolution, high frequency seismic systems, especially a HUNTEC Deeptow Boomer (resolution: about 30 cm). This facilitated the selection of phosphorite-prospective areas, before the sampling program started. Bottom reflectors composed of overlapping hyperbolae (without subbottom reflectors) indicating a hummocky surface (with undulations 1–15 m high and 500–100 m wide) yielded generally high phosphorite contents (HANSEN; FALCONER et al. this vol.). On the other hand, areas with continuous bottom (± subbottom) reflectors from a smooth to irregular, rolling bottom topography without any hyperbolae yielded considerably less or no phosphorite. There is a surprisingly good correlation of the distribution of these "seismic facies types" with the phosphorite concentrations based on sampling. Also the degree of blackening of the side-scan profiles gives indications of the concentration of phosphorite nodules exposed at the sea floor (KUDRASS & VON RAD (a) this vol.).

Most of the 550 sediment samples were obtained by the newly developed large pneumatic grab sampler.

In most samples we find the following sequence (VON RAD & RÖSCH this vol.):

(1) a superficial layer of Neogene, highly bioturbated glauconite-rich foraminiferal sand/silt (a few cm to 150 cm) with a zone of phosphorite nodules (a few cm to 60 cm thick) which occurs as lag deposit mostly at the base of the glauconite sand;

(2) This is underlain by a white Late Eocene-middle Oligocene, ± semiconsolidated nanno chalk or ooze which was reached in most grab samples, especially in the prospective areas.

In the prospective areas the glauconitic foraminiferal fine sand contains 10–17 weight-% of phosphorite or on the average 54 kg/m^2. The phosphorite concentrations are, however, characterized by a strong, as yet unexplained small-scale variability and patchiness. According to preliminary shipboard reserve estimates, the surveyed prospective areas in the SO-17 areas 1–4 (166 km^2) contain approximately 18 million tons of phosphorite (cutoff at 40 kg/m^2; for a better shore-based estimate of the phosphorite-reserves see KUDRASS this vol.).

Although major technical problems have to be solved, before this horizontally and vertically highly variable phosphorite deposit can be mined, the participating German companies are investigating with their New Zealand partner a plan to continue the present prospection phase toward a mining test, which might lead to a joint mining venture.

Acknowledgements: We are indebted to all shipboard scientists (Table 1) from DSIR (NZOI, New Zealand Geological Survey, etc.), Fletcher-Challenge Ltd., BGR, Preussag AG (Hannover), DST-Salzgitter (Lingen), as well as to Captain KLAASSEN and his efficient crew for the excellent cooperation which made it possible to collect so much new information on the Chatham Rise phosphorites.

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Plate 1

Fig. 1: R/V SONNE in Wellington Bay.

Fig. 2: HUNTEC deeptow seismic system ("boomer") being lowered to sea over SONNE's A-frame.

Fig. 3: German (AMR) deeptow system (deeptow fish with 3.5 kHz subbottom profiler, side-scan sonar etc.).

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Plate 2

Fig. 1: Large grab sampler with self-contained pneumatic drive (Preussag and Peiner AG). Closing power 1.5 t, capacity 0.8 m^3, dead weight 1.8 t, depth of penetration: 0.5 (0.7) m, total recovery: 700 t of sediment during 530 stations.

Fig. 2: Vibrating sieve device (hopper and shaker) for the separation and recovery of phosphorite in two size fractions (> 8 mm and 1–8 mm).