ARCHAEOLOGICAL PROGRAM

by

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HISTORICAL RESEARCH PROGRAM

A world-wide research program was initiated in 1985 under the direction of historian Professor Sir John Hale, an authority on colonial maritime history. The goals of the historical research program were to identify the Manila Galleon shipwrecks which provided the greatest potential for an archaeologically and commercially successful recovery program, to determine, as precisely as possible, the shipwreck location, and to obtain historical information which would facilitate the search and recovery operations.

PSR carried out an extensive search of historical archives to determine the Spanish galleon losses in the Pacific. This archival research was undertaken by maritime historian Dr. David Hebb and economic historian Dr. Peter Earle, both specialists in the Spanish Colonial era. They employed traditional methods of investigation using literature and primary source materials as bases for information. This research team spent one and a half years (1985-86) working in libraries and archives in London, Seville, Simancas, Madrid, Manila, Rome, Guam, Mexico City, and the United States.

The primary source information was in manuscripts by contemporaries who participated in salvage efforts or who were close enough to provide reliable accounts. The researchers also reviewed literature on international trade and shipping from the 16th to the middle of the 19th century. This material included reports from the Jesuit mission operating in the Marianas in the late seventeenth century, ships' manifests, official proclamations, pilot's reports, general histories of the region and inquires resulting from galleon losses.

Altogether the research yielded detailed circumstances of 44 Manila Galleon losses in the Pacific during this time period. All but a few cargoes in these wrecks were recovered by contemporary Spaniards and local inhabitants. The historical records indicated that five of these ships were lost in the Mariana Islands. Based on the information assembled by the historical research team, as well as practical recovery and contractual considerations, PSR identified the *Nuestra Señora de la Concepción* as the primary target for search and recovery operations.

The *Concepción* was shipwrecked on September 20, 1638, off the coast of Saipan, now the capital island of the Commonwealth of the Northern Mariana Islands. Historical information which contributed to PSR's choice of the *Concepción* included the following: (1) the *Concepción* was the largest Manila Galleon built up to 1638; (2) she carried an unusually large, valuable, and historically interesting cargo; (3) the circumstances of her voyage and loss were particularly interesting and historically significant; (4) the wreck site was apparently readily accessible, in reasonably shallow water; and (5) previous Spanish salvage efforts had apparently been restricted to recovery of cannons and anchors. Practical considerations contributing to choosing the *Concepción* included: (a) political factors: The Commonwealth of the Northern Mariana Islands (CNMI) is a U.S. Commonwealth, which facilitated contract negotiations and legal agreements; (b) logistical factors: the CNMI has strong communications and transportation linkages with the international community; (c) government support: the CNMI government was enthusiastic about the prospect of recovering an important part of the island's heritage, as well as the favorable international exposure which could result, and about the potential for an equitable share of the financial returns from the operation.

Historical research continued both while recovery operations were underway and after on-site work was completed, in order to supplement the archaeological report with a comprehensive account of the history of the Manila Galleon trade and the wreck of the *Concepción*. Concurrently, specialist studies of recovered artifacts were undertaken. These studies included research of the historical background and significance of gold jewelry and other decorative artifacts, stoneware and earthenware storage jars, porcelain shards, and inscriptions found on many of the artifacts. The results of these analyses together with photographs and the archaeological illustrations of many of the recovered artifacts are also included in the archaeological report.

SITE DESCRIPTION

The *Nuestra Señora de la Concepción* was wrecked in Agingan Bay, on the southwest coast of Saipan, an island in the Northern Marianas archipelago in the western Pacific (*Figure 1*). The Northern Marianas archipelago represents the leading edge of the Philippine Plate which abuts the western edge of the northwest-moving Pacific Plate. The convergence of the plates has produced the oceans' deepest trench system, the Marianas Trench, just east of the archipelago and considerable ongoing earthquake and volcanic activity at the plate boundary. The volcanism, in turn, has given birth to the Northern Mariana Islands.

Crescent-shaped Agingan Bay is exposed to the southwest and vulnerable to frequent typhoons which threaten the islands. Agingan Bay is partially enclosed by Agingan Point to the northwest and Obyan Point to the southeast. Near shore, a fringing coral reef runs along the embayment. The fringing reef converges with the shore at Agingan and Obyan Point and encloses a shallow lagoon, averaging less than 1m in depth at mean low water, and 75m wide at its widest point. The shoreline of the embayment is characterized by steep, wave-cut cliffs, ranging from 1 to 7m in height, and probably representing the seaward side of a former fringing reef, now elevated above sea level by geological uplifting.

The fringing reef is partially exposed at low tide but submerged to a depth of 1 to 2m at high tide. Its outer edge is characterized by a complex, radiating spur and groove system, typical of tropical coral reefs. The eroding forces of storm waves, buffered from the shore by the fringing reef, have created steep-sided crevices, tunnels, undercuts, and up to 6m deep gullies aligned perpendicular to the shore. The crevices and gullies have partially filled with eroded sediments, ranging in size from fine sand to coral boulders weighing several hundred kilograms. The depth of the deposits varies, reaching a maximum of 4m in some gullies.

On its seaward side, the fringing reef slopes down sharply, at an angle of approximately 30 degrees, to a depth of 12 to 15m (*Figure 2*). At the base of the fringing reef, the seabed is relatively flat, interrupted by occasional coral outcrops, and scoured smooth by the eroding action of mobile sediments. Sedimentary deposits are restricted to infrequent seabed depressions which also have acted as traps for *Concepción* artifacts. The slope of the seabed is shallow from the base of the fringing reef to a depth of 45m, approximately 400m from shore where another relict, fringing reef is also evident. At this point, the sea floor again slopes down sharply to a depth of 70m, levels off briefly, then descends again to the bottom of the 370m deep channel that runs between Saipan and the island of Tinian, 5km to the south.

The entire reef system is largely devoid of living corals. The environmental monitoring surveys indicated that only 2-3 percent of the seabed in the survey/recovery area was populated by live corals. The area experienced an invasion of coral-consuming Crown-of-Thorns starfish in the late 1960s, and the reef has not yet recovered. In fact, most of the reef system appears to have undergone very little net coral growth over the past 350 years, based on the observation that even the heaviest, least mobile artifacts recovered were not heavily overgrown by corals. Artifacts, primarily storage jars, found at depths between 45 and 60m were encrusted with some calcareous growth, including coral, while those below 60m were nearly clean.

Diving conditions were generally favorable with water temperatures averaging 28 degrees Celsius and underwater visibility averaging 30m, with a maximum of 75m. All diving was conducted in daylight hours during the months of January to July during the period of prevailing Northeast Trade winds which occasionally made for rough seas in the shallow waters around the fringing reef. However, wind velocity seldom exceeded 15 knots and, in ten months of work on-site, inclement weather caused only four days of downtime.

Strong currents were sometimes a problem for divers. A complex current regime exists in Agingan Bay. Currents, with velocities of up to three knots, flow through the channel between Saipan and Tinian. The rapid current flow through the narrow channel tends to establish a counter-flowing eddy current in Agingan Bay so that current direction adjacent to the shallow water fringing reef was frequently opposite to that at the deep water relict reef. Rapid changes in current direction were common, with slack water rarely lasting more than a half hour. Current shear was also observed in deeper water with current direction changing at about mid-depth. Thermoclines of 3 to 4 degrees Celsius were sometimes evident at about 40m.

Aerial view, towards southeast, of Agingan Bay with recovery vessel Tengar moored on site

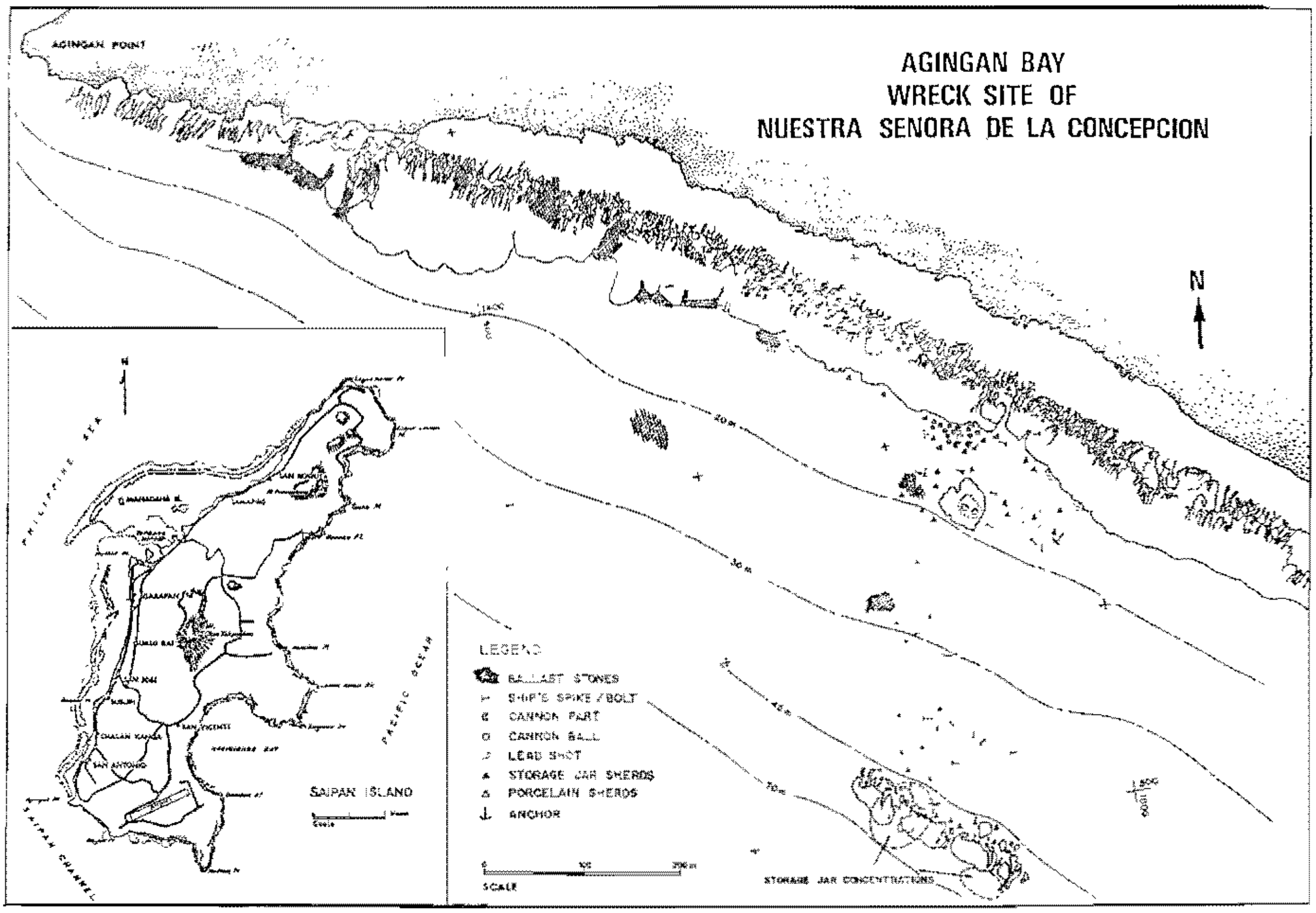


Figure 1

Artist's impression of recovery site and on-going operations

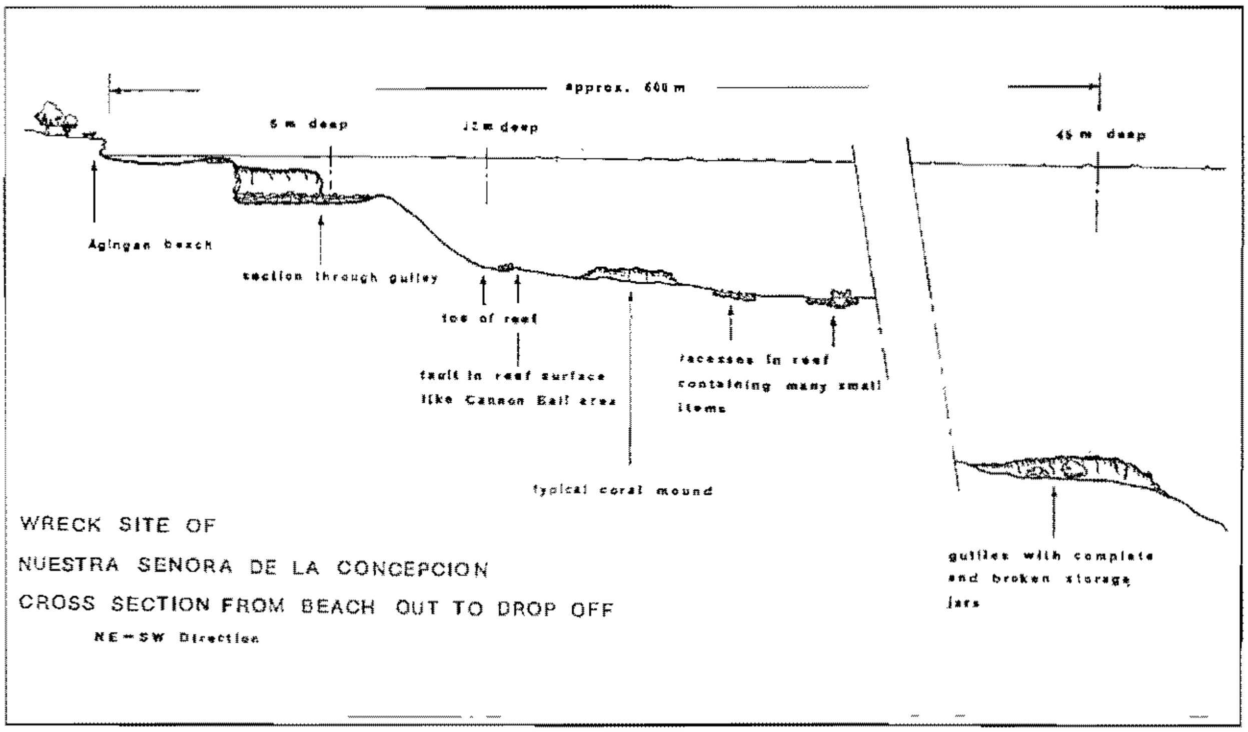


Figure 2

The *Tengar* was designed as a maintenance vessel for the offshore oil industry, and its primary task was the installation and removal of scaffolding for grit blasting and painting on production platforms. Pacific Sea Resources modified the vessel to serve as its base for marine archaeological recovery operations. The *Tengar*'s inherent features, such as its good maneuverability, large working deck area, sufficient accommodation for the thirty crew members, and its multi-point mooring system, made it well suited to its new task both in terms of onboard facilities and overall layout (*Figures 3-5*).

The *Tengar* is 45.7m in length by 12.2m beam with a 2.1m draft. The vessel has a full hull form making it a stable and spacious platform. *M/V Tengar* has its accommodation block situated aft of the main working deck. This arrangement allows the 12-ton lift revolving crane, installed on the raised foredeck, equal accessibility to both port and starboard sides as well as the main deck area. The crane is hydraulically operated and fitted with a telescopic boom which can extend to a 24m radius. A further advantage of the *Tengar*'s layout is its ability to moor bow toward either reefs or beaches. This minimizes the possibility of propellers and rudders hitting the seabed, unlike the conventional supply boat design in which the working deck is aft of the superstructure, requiring the vessel to be moored stern-in for shallow water working efficiency.

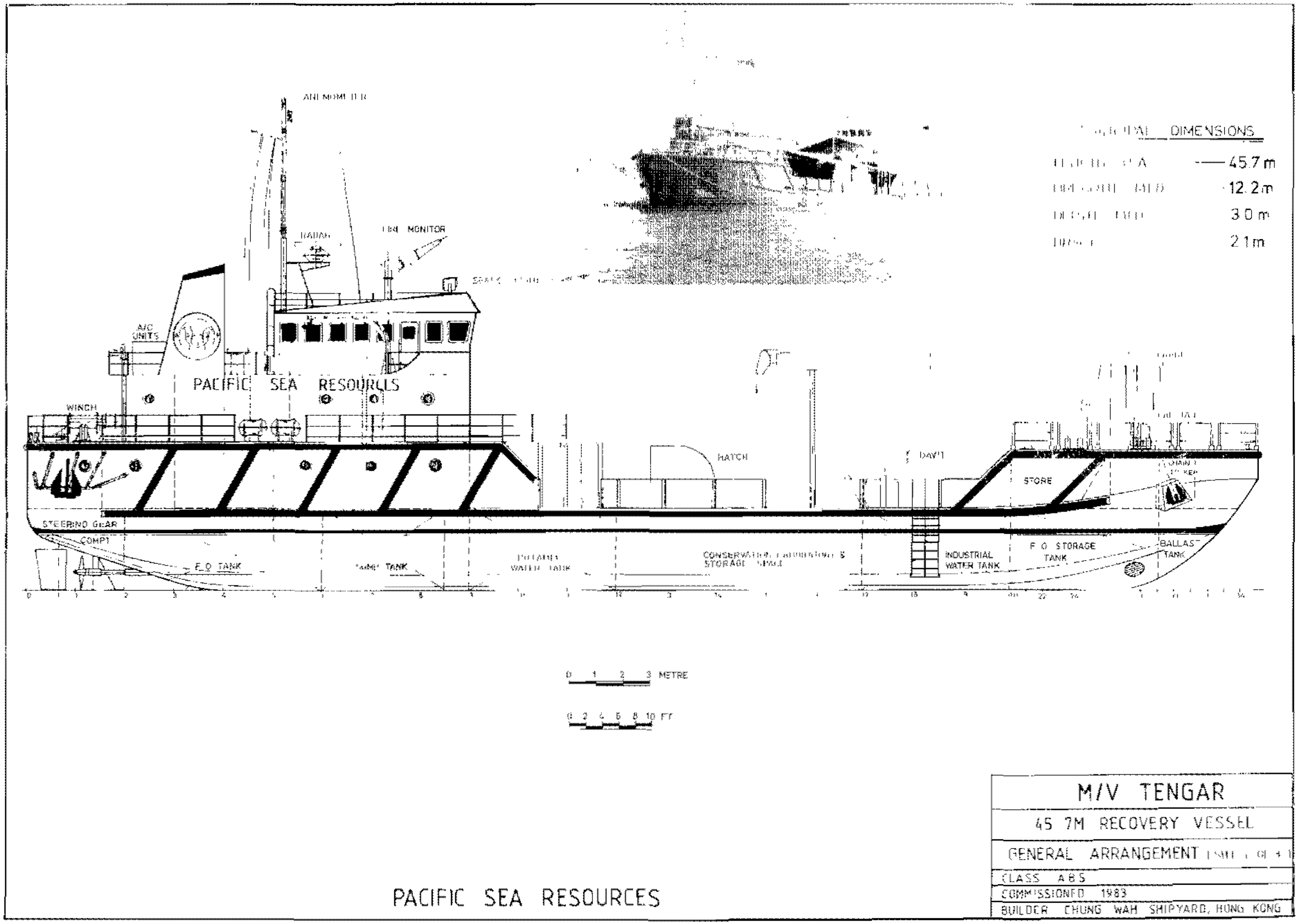
The *Tengar* is highly maneuverable with twin screw propulsion and a 250hp bow thruster. Main propulsion is provided by two 360hp GM engines which at full power drive the ship at 9 knots. Anchoring on-site is by means of a four-point mooring system, with two 1-ton stockless bow anchors on 180m of 25mm chain port and starboard and two 3-ton Stevin stern anchors aft with 600m of 32mm wire each. Hydraulic capstans forward and aft allow mooring lines to be easily manipulated in situations where fixed ground tackle is used in addition to conventional anchoring. The *Tengar* was usually secured in a six-point moor, because of the proximity of the shallow reef, often within 20m of the bow, and the need to keep the vessel perpendicular to the prevailing seas.

Three GM diesel 160kw generators provide the electrical power to drive the ship's services plus the extra pumps, diving compressors, welding machine and other electrical equipment. The fuel capacity is 120 tons, giving a 4,500 mile cruising range at 7 knots. The *Tengar* has a fresh water storage capacity in four midships tanks, totalling 400 tons. In addition, a reverse osmosis water maker can supply 7 tons a day. Large freezer-chiller rooms and dry storage areas allow the *Tengar* to remain on station for long periods, a prerequisite in remote areas. To comply with U.S. Coast Guard requirements, the vessel is also fitted with an oily water separator and a domestic sanitary system including a sump storage tank which holds 20 tons of waste fluids.

The *Tengar*'s living spaces include two decks of cabins, washrooms, galleys and messing facilities. Up to 39 people, sufficient for most archaeological projects, can be comfortably accommodated at any one time. An office, computer room and photo lab are also situated within the main block. Below decks midships are two archaeological support spaces. On the starboard side there is a conservation laboratory where all recovered artifacts are treated and stored. Occupying one corner of this space is an air-conditioned room containing PSR's computerized image capture system. The port side below decks area is utilized for storage of spare parts and specialized equipment.

The *Tengar*'s wheelhouse has a clear all-around view. Dashboard-mounted main engine and bow thruster controls enable a high degree of maneuverability, an important feature when anchoring close to dangerous reefs. The *Tengar*'s navigational instruments include satnav, gyrocompass, radar, depth sounder, auto pilot, as well as VHF, UHF and SSB radio sets. In the aft part of the wheelhouse, there is a computer room housing PSR's archaeological database management system. This is linked by cable to the image capture station located below decks.

Essential to any underwater operation is the diving system. The *Tengar*'s comprehensive system is situated forward on the main deck. For ease of maintenance and quiet operation, the two HP, and the two LP electrical compressors, the HP back-up bottle bank and the diving control panel were installed in a sheltered area under the crane. Divers and hoses enter the water through a starboard bulwark opening which is equipped with a wide entry/exit ladder. A large workbench complete with welding and cutting gear is situated midships, making onboard fabrication and alteration activities possible.

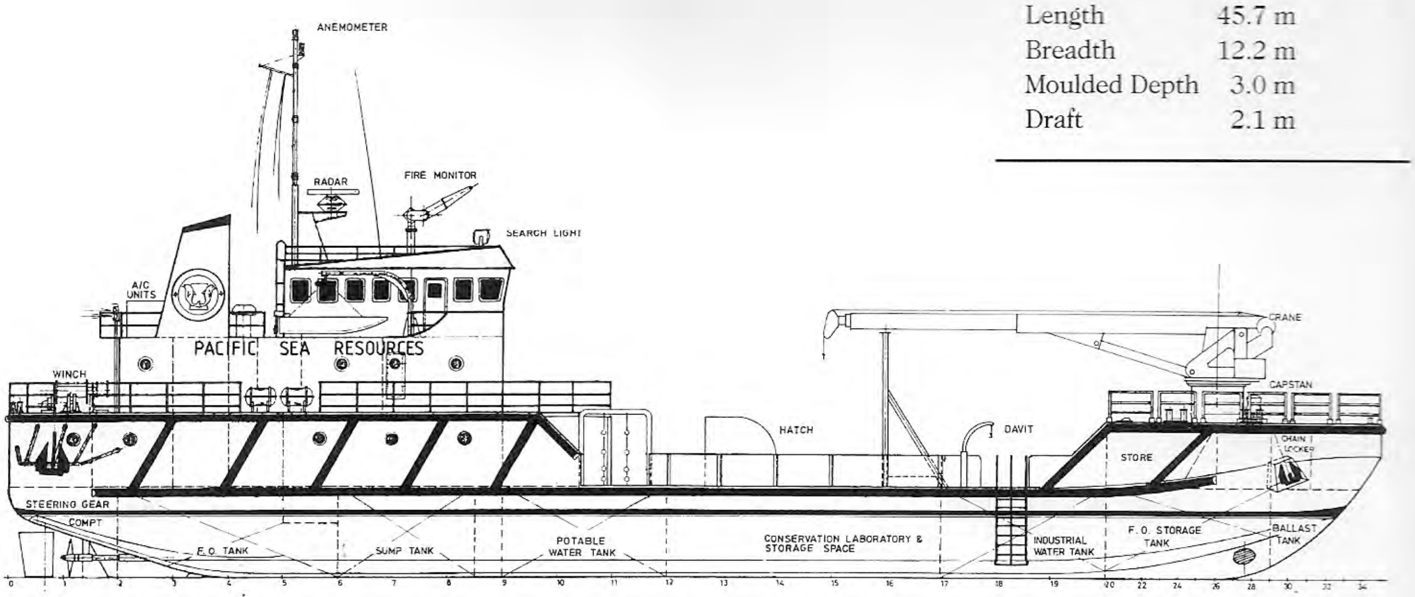


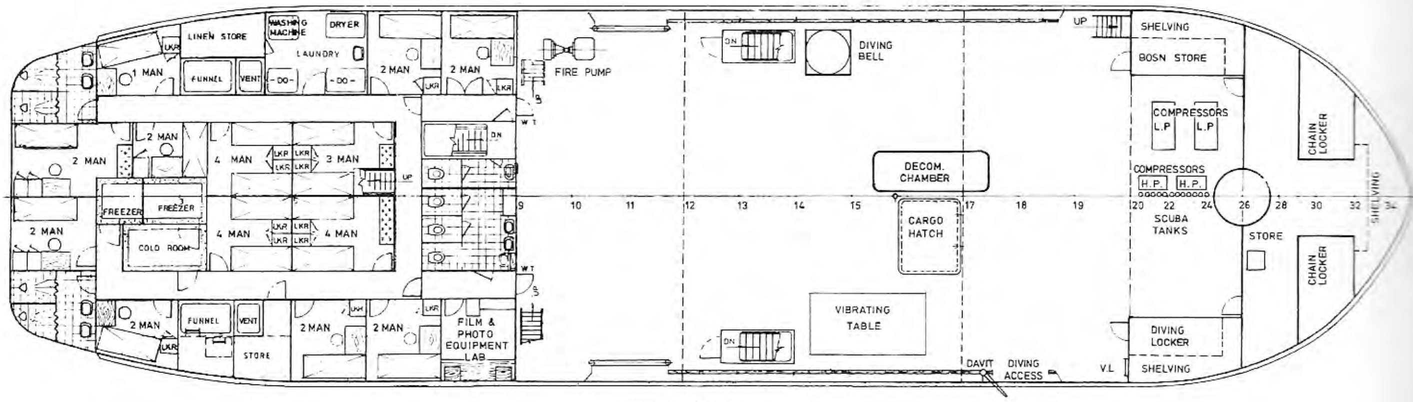
DIMENSIONS
45.7 m
12.2 m
3.0 m
2.1 m
RADAR
MONITOR
A/C UNITS
PACIFIC SEA RESOURCES
WINCH
HATCH
DAVIT
STORE
STEERING GEAR COMPT
F.O. TANK
TANK
INDUSTRIAL WATER TANK
F.O. STORAGE TANK
BALLAST TANK
0 1 2 3 METRE
0 2 4 6 8 10 FT
M/V TENGAR
45 7M RECOVERY VESSEL
GENERAL ARRANGEMENT
CLASS ABS
COMMISSIONED 1983
BUILDER CHUNG WAH SHIPYARD, HONG KONG
PACIFIC SEA RESOURCES

M/V Tengar

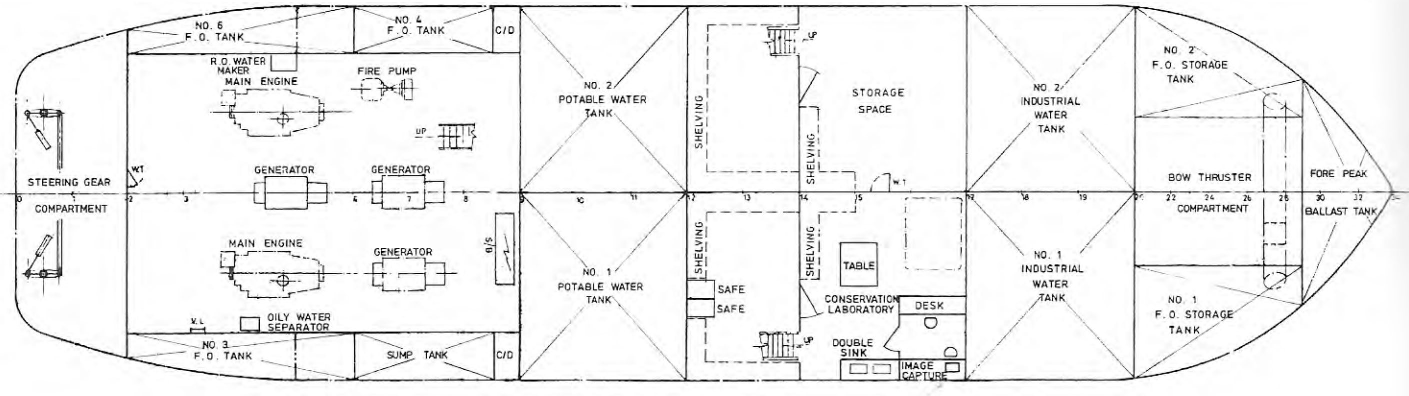
Archaeological Recovery Vessel

Length	45.7 m
Breadth	12.2 m
Moulded Depth	3.0 m
Draft	2.1 m





MAIN DECK



BELOW MAIN DECK

RECOVERY VESSEL SPECIFICATIONS & DRAWINGS

M. V. TENGAR

S P E C I F I C A T I O N S

DIMENSIONS - LENGTH (LOA)	:	45.7 M
- BREADTH	:	12.2 M
- DEPTH	:	3.0 M
- DRAFT	:	2.1 M
- DECK MIDSHIPS	:	16.5 M x 11.8 M
GROSS TONNAGE	:	648 tons
TYPE OF VESSEL	:	Archaeological Recovery Vessel
FLAG	:	Panama
CALL SIGN	:	HO - 2617
BUILDER	:	Chung Wah Shipyard, Hong Kong
OWNER	:	QAF SOLUS
CLASS/LOADLINE	:	A.B.S. Maltese Cross A1 + AMS
YEAR BUILT/COMMISSIONED	:	1983
TOTAL HORSEPOWER	:	720 BHP--Two GM 12V71 Diesel engines--Twin screw, Fixed 4-blade 1.24 M diameter
SPEED	:	8 knots maximum
RANGE	:	4,500 miles at 7.0 knots
GENERATORS	:	Three Stewart & Stevenson 6GDT-220/GM6-71T 160KW/415V/3PH/50HZ
BOW THRUSTER	:	Jastram Werke BU-40F, 250 HP
WATER MAKER	:	Sweet Water Reverse Osmosis Unit, 2,000 gpd
OILY WATER SEPARATOR	:	One Taiko Kikai Model UST-03, 0.25 m3/hr 15 ppm
SUMP SYSTEM	:	20 ton treatment/holding tank with discharge pump
FUEL CAPACITY	:	120 tons
POTABLE WATER CAPACITY	:	200 tons
INDUSTRIAL WATER CAPACITY	:	200 tons
NAVIGATION/COMMUNICATIONS	:	SSB/VHF/UHF/Satnav/Gyro/Radar/Auto Pilot/Sextant/Speed Log/Anemometer/Compass/Weather-fax/Walkie-Talkies/etc.
ANCHORS	:	Two forward 1.0 ton with 165 M of 25mm chain
	:	Two aft 2.5 ton with 600 M of 32mm wire
	:	Two spare 3 ton Stevens

CAPSTAN/WINDLASS	: Two James Robertson 4-ton line pull vertical electric hydraulic capstan/windlass
AFT WINCH	: James Robertson, 10-ton line pull, double drum winch
DECK CRANE	: Pettibone 40 PMP Hydraulic Crane with max load 18.3 tons at 3 M and max outreach 24 M
TENDERS	: Two 5 M Whalers with 40 HP outboards : One 4 M dingy with 10 HP outboard
LIFE SAVING EQUIPMENT	: Four 20 men inflatable liferafts to SOLAS : 16 lifebuoys to SOLAS : Lifejackets (USCG), pyrotechnics, line throwing rockets, etc.
FIRE-FIGHTING EQUIPMENT	: One Naniwa fire monitor pump, 180 m3/hr with 135 M head : Two fire/ship service pumps, 30 m3/hr with 25 M head : Dry powder/C02/Water extinguishers
FREEZER	: Two 9 cubic meter freezers
CHILLER	: One 9 cubic meter chiller
DIVING SYSTEM	: Four sets surface supply hardhats : Five sets scuba equipment
DIVING/OBSERVATION BELL	: Galeazzi Sat System Bell, 3 persons
DECOMPRESSION CHAMBER	: Double lock, 1.2 M diameter chamber
DIVING COMPRESSORS	: Two L.P. electric air compressors, 85 cfm : One H.P. electric air compressor, 11 cfm : One H.P. electric air compressor, 6 cfm
SALVAGE EQUIPMENT	: Four portable Yanmar diesel pumps, 50mm : Welding machine, 400 amp : Portable Yanmar generator, 2kw : Fuel and water discharge hose, 600 M : Underwater cutting and welding equipment : Underwater hydraulic powerpack system
DATA ACQUISITION SYSTEM	: Laser disc storage system utilizing TARGA 16 image boards and 4 networked AT-PC Dellfield computers. Video images from Sony Pro Handycam CCO-V9 cameras
ELECTRONICS	: One Magnetometer : Four underwater metal detectors : Underwater video camera system
SAFES	: Two security safes
ACCOMMODATION	: Two single berth cabins = 2 persons : Eleven two berth cabins = 22 persons : One three berth cabin = 3 persons : Three four berth cabins = 12 persons 39 persons

SEARCH AND SURVEY METHODS

The on-site archaeological program began with a predisturbance survey based on historical research. Interpretation of various historical sources suggested that the *Concepción* had wrecked off Agingan Point and broken up along the fringing reef of Agingan Bay. The survey was initiated on 14 March, 1987, and was continued through the first season ending in July with the onset of the typhoon season. PSR's first task was to evaluate the environmental characteristics of the area in order to determine the most appropriate search methodology. It has been established that the environmental attributes of a wreck site are a controlling factor in determining the dispersion and degree of survival of artifacts. Since the Agingan Bay wreck site encompasses an exposed, typhoon-ravaged area, there are no large deposits of undisturbed sediment which could harbor intact wreck remains. Thus, the remains were expected to be widely scattered, fragmented, and devoid of organic content. This dictated a careful search pattern over a wide area.

A priority from the outset was to establish a variety of survey techniques which would cover the area systematically and provide an accurate plot of the artifact distribution pattern which could facilitate archaeological interpretation. This survey program was designed to thoroughly search a 1.5 km strip of coast from Agingan Point to Obyan Point; from the shoreline to a depth of 240m, approximately 800m from the shore. PSR first searched the shore itself, finding a significant amount of blue and white Ming dynasty porcelain shards on the beach. These porcelain shards were dated as contemporary with the *Concepción* voyage by specialists in Chinese ceramics at London's Victoria and Albert Museum, providing the most important evidence that the *Concepción* was lost in Agingan Bay.

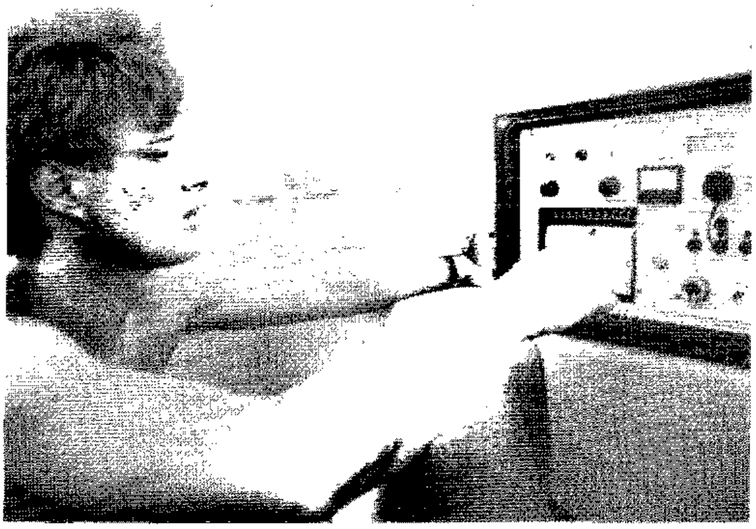
Search and survey methods employed included the use of transect lines, metal detectors, magnetometers, towed diver sleds, drift dives, a Remotely Operated Vehicle (ROV), a mini-submarine, and an acoustic positioning system. The use of transect lines was the most common method for conducting the diver searches and was found to be an efficient and systematic means of covering large areas of the seabed. A pair of divers would swim along the length of the transect line (50 or 100m) and search up to 5m either side of the line. Their visual search was supplemented by the use of metal detectors. Artifacts were sometimes found wedged in crevices and under ledges in the bedrock hence all of these were checked thoroughly. Once an area had been covered, the transect line would be moved in 10m increments across the bottom.

Ordinarily, a magnetometer can be a useful tool to locate an underwater wreck site. This instrument detects anomalies in the Earth's magnetic field created by the presence of ferrous objects, such as cannon, anchors and iron shot. This is particularly relevant in a reef area, where artifacts and wreckage may be camouflaged by coral or be covered by sand. The survey operation was conducted by towing a magnetometer behind a work boat which was guided by radioed instructions along transit lines spaced at close intervals. The transit line separation was determined by a theodolite located at Agingan Point or Obyan Point. When the magnetometer registered a significant anomaly, its position was marked with a buoy for later examination by divers.

We undertook a magnetometer survey in April 1987. Unfortunately, the efficacy of this operation was greatly reduced by a preponderance of ferrous World War II debris which exists in the area, as Saipan was the scene of heavy bombardments and fighting in World War II. Consequently no significant wreck remains were located by magnetometer.

To cover large areas of the seabed rapidly, particularly in deeper water, towed sled searches were conducted. Divers were towed by work boats using a simple underwater sled by which the diver could control his depth. A diver would signal the boat handler if an object of interest was sighted so that he could inspect it immediately or buoy it for later examination. Current-aided SCUBA drift dives also served as a means of visual search in deeper waters. Divers would mark anomalies with inflatable buoys.

Because of diver-time limitations in deep water, PSR also employed a Mini-Rover, a small ROV, to facilitate these searches. This unit is essentially a tethered, self-propelled video camera with a small manipulative claw. The ROV could operate independently, staying down for any length of time at depths up to 150m, and provide a permanent record of the dive on videotape. A systematic ROV survey of the deep water zone, where storage jars had been seen by divers, was conducted providing several days worth of video footage for analysis. A substantial number of storage jars were located by this method. The Mini-Rover was compact and light enough to be



Magnetometer operator David McIntosh in workboat during site survey

SCUBA diver Entu Nawin with Elsec metal detector and cannon ball located during transect line search

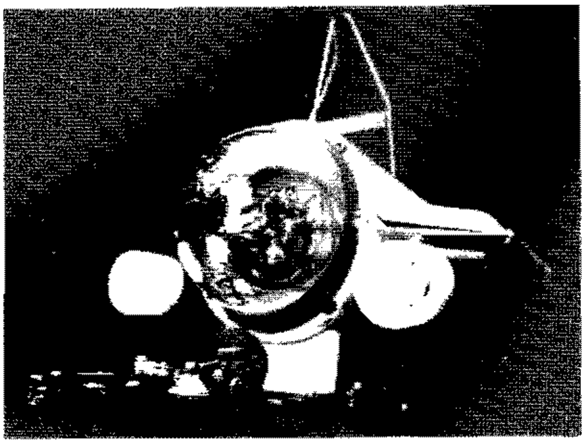
Diver with 1.9 ton anchor from Concepción, the first major artifact discovered during survey deployed from tenders, with power supplied by a portable generator. However, the ROV could only be operated in low current conditions since in currents over 1.5 knots, the ROV had difficulty maneuvering due to the drag on the umbilical.

For inspecting the seabed in depths between 70 and 240m, PSR employed a three person mini-submersible, the Perry PC-1201. The submarine could accommodate a pilot and two observers for up to eight hours at a time.

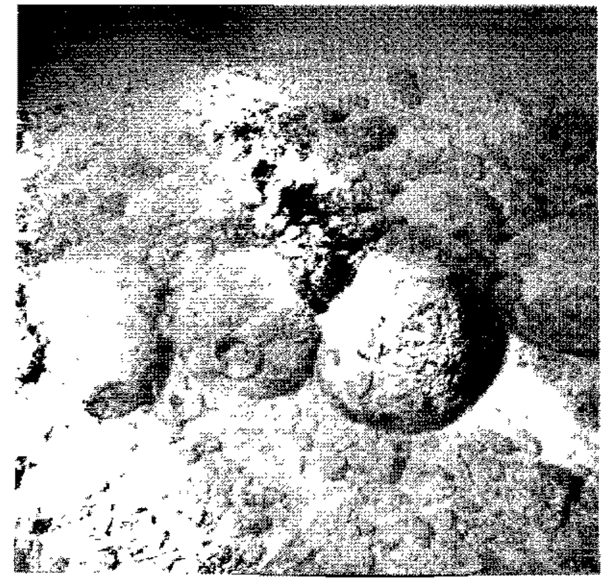
In the waters of less than 20m, accurate plotting of the locations of the surveys, artifacts, and underwater features was ensured by using an Oceano Underwater Acoustic Positioning System. Four transponders were placed on tripods on the seabed in a rectangular array with their positions relative to each other and the ship being determined by acoustic interrogation. Once the calibration was completed, the array could be used to establish the position of a diver-carried transponder, which in turn could provide X, Y, and Z coordinates for each artifact or feature on the seabed.

Accurate plotting of underwater topography and artifact locations was important. A master chart was prepared showing all pertinent seabed features, with overlays for artifact locations and survey areas. During the second field season PSR continued to detail the charts, concentrating on the intricate network of gullies within the fringing reef. A more traditional method of surveying was adopted for this region; each gully was mapped at a scale of 1:200 by a snorkel diver and this in turn would be reduced to 1:1,000, fixed by land datum points and then added to the master chart. Aerial photography of the coast was used as a further means of ensuring the accuracy of the master chart. The plotting of the artifacts within the gullies themselves is described in the "Artifact Registration and Handling" section.

Deep water survey team inspects results of photomosaic of storage jar concentration in 55m water depth



Mini-rover (Remotely Operated Vehicle)



Storage jars as investigated by ROV at 58 meters

MINI-ROVER ROV SYSTEM TECHNICAL SPECIFICATIONS

GENERAL OUTLINE

Operational depth	0 to 400 ft (121 meters)
Size	Length 26" less skid (66 cm) [illegible] [illegible]
Speed	[illegible] 76 m sec ≥ [illegible] knot current
Weight	45 to 55 [illegible]
Buoyancy	6 lbs ± 2 [illegible] sea water Nominal buoyancy .5 lbs typically
Trim	Diver lead weights — adjustable
Stability	Gravity stabilized in roll and pitch

VIEWING SYSTEM

TV camera	Low-light color TV camera (Newvicon) with 4 8 mm/f 1 8 lens 6 fc full video 43 db signal-to-noise ratio [illegible]
[illegible]	Camera mounted [illegible] mechanism [illegible] plexiglass end dome Up 45° off horizontal Down 55° off horizontal Speed 45° per second minimum
Lights	Two 150 watt 120 v, long-life quartz halogen lights — one port one starboard

UMBILICAL CABLE

Cable length	250 ft standard 1200 ft maximum
Size	63" outer diameter
Strength	≥ 100 lbs minimum
Construction	Outer abrasion jacket of [illegible] [illegible] 75 ohm coax 2 #16 AWG power conductors 2 spare mini-coaxes All fully isolated Outer jacket of Hyperlon rubber

PROPULSION

Horizontal (FWD RE, CW/CCW)	Two thrusters — one port one starboard 4 lbs thrust each peak Speed and direction proportionally controlled
Vertical (UP/DOWN)	One thruster — centrally located 3 lbs thrust peak Speed and direction proportionally controlled

All thrusters are remotely controlled from the Surface Control Console via joysticks located on the Hand Control Box.

SUPPORT REQUIREMENTS

Power	120 VAC/240 VAC ± 20% 50 60 Hz 500 watts maximum 6 6 amps (120 VAC)
Crew (minimum)	Two persons — one pilot/technician one pilot/tender
Vessel	Any stable boat or floating platform that will safely support the weight and loading of personnel and equipment and is appropriate to the task and budget

NAVIGATIONAL AIDS

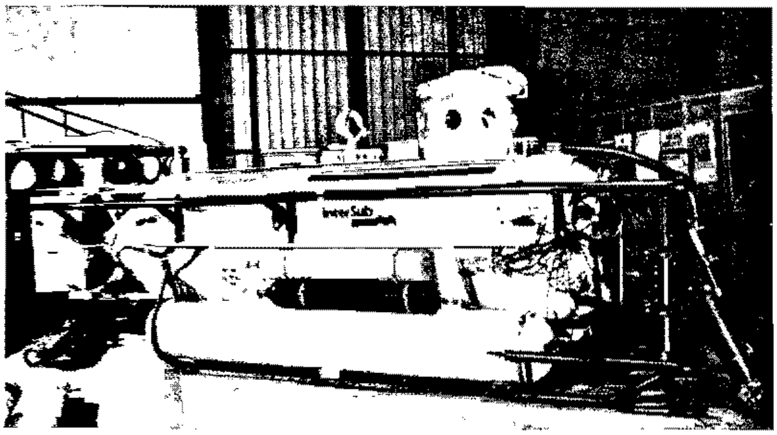
Depth	Divers depth gauge 0 to 300 ft S W
Heading	Large compass pressure compensated

The depth gauge and compass are mounted on a clear plexiglass plate in the lower view of the TV camera allowing direct viewing while flying the vehicle over bottom terrain. A remote reading digital depth gauge is available on special order.

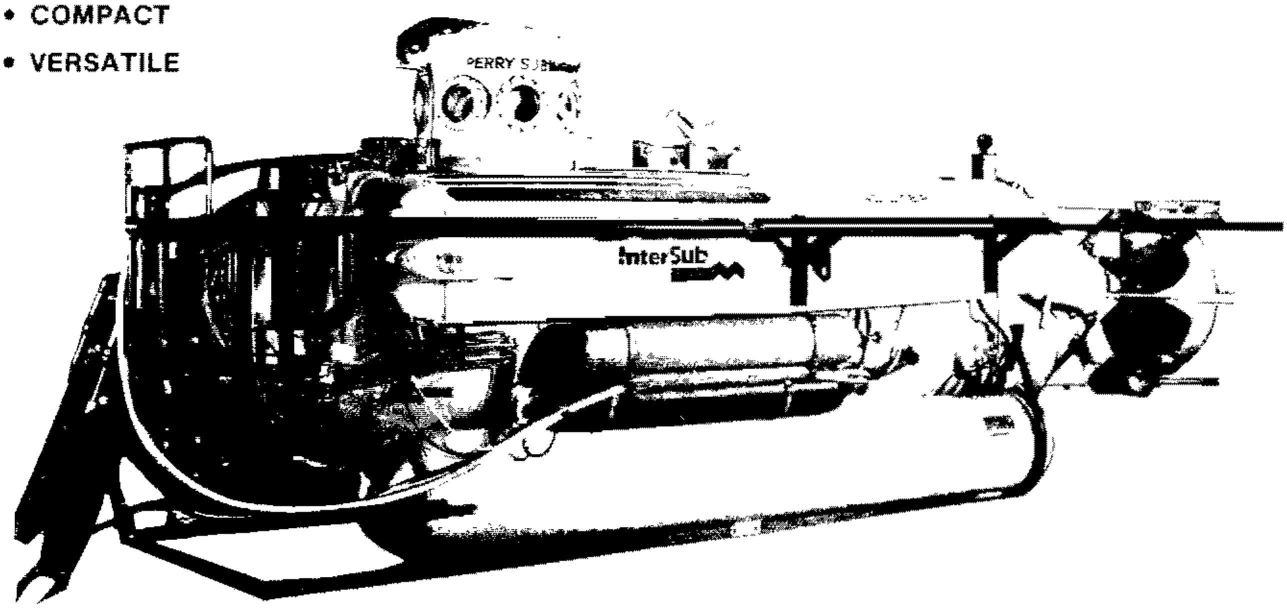
Deep Sea Systems International inc has an ongoing Product Refinement Program. Specifications are subject to change

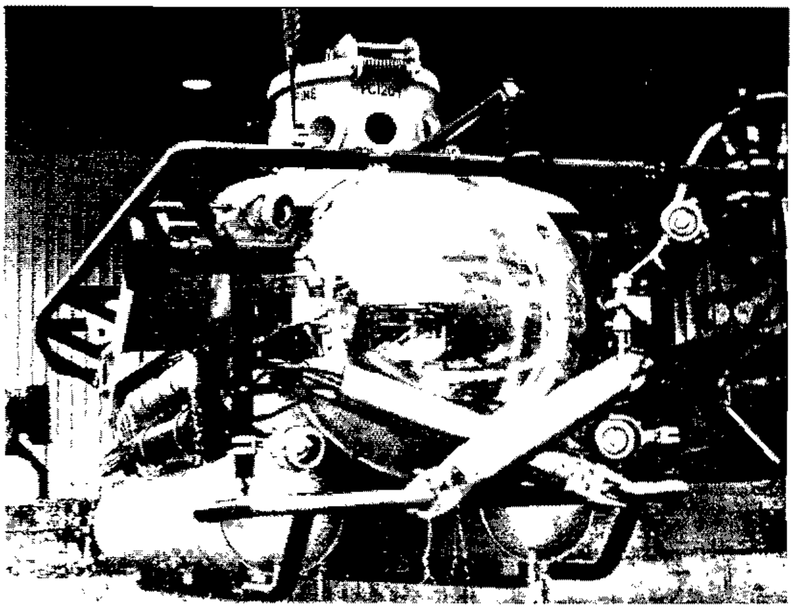
PERRY
PC-12
SUBMERSIBLE

A 2-Man, 1200-FSW-Rated Subsea Work Submersible



- COMPACT
- VERSATILE





- Crane Weight: 8 tons
- Speed: Up to 3 knots
- Typical Bottom Time: 8 hours
- Outfitted for survey and inspection of pipelines and offshore drilling rigs
- Manipulators available for many repair tasks that would normally require divers

PC1201 General Specifications:

Classification: +A1 Manned Submersible by the American Bureau of Shipping (ABS)
Builder: Perry Submarine Riviera Beach, Florida
Depth Rating: 304m (1000 FSW)
Length: 7.0 m (23 ft.)
Width: 2.5 m (8 ft. 3 in.)
Height: 2.9 m (9 ft. 7 in.)
Draft: 1.8 m (5 ft. 8 in.)
Crew: Three (3) persons
Payload: 340 Kg (750 lb.) in excess of standard equipment and crew
Weight: Approximately 7,000 Kg (15,400 pounds)
Main Propulsion: 7.46 KW (10 HP) with rudder
Maneuvering Thrusters: Four (4) x one (1) HP with 32 Kg (75 pounds) thrust each
Speed: 3.5 knots maximum
Endurance: to 12 Hours on a single charge
Emergency Life Support: Three (3) crew for seven (7) days
Power: Two (2) pods, 120 Volts - 17.4 KW and 24 Volts - 3.5 KW each or 41.8 KW total using new, highdensity batteries
Pressure Hull: 1.22 m (48 in.) inside diameter with internal stiffening rings
Battery Pods: 500 mm (20 in) outside diameter with internal stiffening rings and removable end caps for access to batteries
Material: A-516 and A-537 low temperature service steel
Viewports: One (1) 910 mm (36 in.) diameter forward looking hemispherical viewport and eight (8) 200 mm (8 in.) diameter flat viewports in conning tower – one (1) upward looking in entrance hatch and seven (7) girdling tower
Penetrators: Multiple spares accommodated in removable plates
Emergency DropWeight: 320 Kg (700 lb)
Exterior Lights: Five (5) 1000 Watt Quartz Halogen
Interior Lights: Four (4) 20 Watt red/white lights
Navigation: KVH Fluxgate compass, Depth sounder, optional CTFM or color imaging sonar system
Manipulator: Wired but not currently fitted
Main Air: 6.8 m3 at 150 bar (240 ft3 at 2,250 PSI)
Reserve Air: 6.8 m3 at 150 bar (240 ft3 at 2,250 PSI)
Main Oxygen: 6.8 m3 at 150 bar (240 ft3 at 2,250 PSI)
Reserve Oxygen: 6.8 m3 at 150 bar (240 ft3 at 2,250 PSI)
Main Ballast Tank: 320 Kg (700 lb)
Variable Ballast Tank: 77 kg (170 lb.)
Hydraulics: 1 HP – 80 Bar (1,200 PSI)
Surface Communications: ICOM 25 Watt base station VHF marine radio with handheld back up
Subsurface Communications: Dual frequency four (4) channel Mesotech 703A underwater telephone with 750 (100 Watt) power amplifier
Instrumentation:
Ground fault detector
Water intrusion alarm panel for main hull compartments, battery pods and shaft seal
Rudder angle indicator
HP/LP oxygen and air system gauges
Propulsion Ammeter
Atmospheric monitoring system (oxygen, carbon dioxide, cabin pressure, temperature and humidity)
Safety Features:
320 Kg (700 lb) emergency drop weight
Water sensors in battery pods, main hull and shaft seal warn of water ingress into any of these compartments
BIBS (Built-in Breathing System), masks and life jackets
Three (3) CSE 100 self contained oxygen generating rebreathers
Ground fault detector system
Soft line cutter
Emergency rescue buoy
500 mm (20 in) Hatch freeboard on surface

DIVING SYSTEMS AND PROGRAM

Underwater survey and recovery operations took place over a wide range of water depths, from 1 to 75m. A variety of diving systems were employed to suit the different conditions of the wreck site, including snorkel, SCUBA, hookah, hardhat, and diving bell (*Figure 6*). The basic face mask and snorkel provided useful tools when excavating holes and cracks in less than 0.5m of water on top of the fringing reef, or when mapping the intricate gully system of the fringing reef.

SCUBA was used as depth and time allowed, primarily for survey work and for excavation where direct control from the research vessel was not required. Support was provided by two fiberglass tenders which were specially modified 5m Boston Whalers, powered by 50hp outboard motors. All divers worked in pairs in two or three groups. One group conducted surveys and excavations in relatively shallow water (less than 10m). By rotating pairs of divers, each diver was able to complete two to three one-hour-plus dives a day, without tiring or risking decompression sickness. Another group of SCUBA divers, using double tanks, simultaneously conducted deep water surveys and storage jar recovery operations in depths of up to 75m. Risk of nitrogen narcosis and the bends limited bottom time to 15 minutes at this depth, with 40 minutes decompression an absolute minimum. U.S. Navy Standard Air Decompression Tables were used very conservatively for dives below 50m with at least a five minute extra safety stop to allow for exertion and the nitrogen buildup associated with several consecutive days of deep diving. Above this depth, computerized decompression meters were used to maximize bottom time, particularly where repetitive dives were concerned.

The research vehicle *Tengar* was equipped with nine single SCUBA tanks and three double tanks, enough to cover the above operations with one full set of gear standing by at all times for emergencies.

Although SCUBA proved to be the most versatile system, most of PSR's shallow water diving was accomplished with hookah gear. This comprised a surface air supply leading to a standard regulator second stage via a 60m umbilical. Since most shallow water diving took place within the fringing reef area, at depths of 5 to 15m, divers could work with few time restrictions. Unlimited air supply and the minimal equipment requirements, which included wet suit, booties, face mask, weight belt, and air hose/regulator, made hookah the ideal system for cramped work in narrow gullies in the reef. Unlike SCUBA, where mobility is important, hookah divers used heavy weights, usually 10 to 15kg, in order to work in a stable, upright, kneeling or prone, position best suited to sediment excavations in gullies. The dive panel on the *Tengar* could supply four hookah divers, two running from amidships and two from the bow in order to prevent potentially dangerous tangling of the hoses.

For excavations and recovery work in the deeper water of 15 to 35m, safety considerations generally dictated the use of a surface-supplied hardhat system. Hardhat allows direct voice communication between the diver and the surface, and is a far more secure system than hookah. The hardhat utilized by PSR was the Aquadyne AH-3, a model made of fiberglass with a lead insert to provide neutral buoyancy. It is a free-flow system, with a continuous flow of air into the helmet and out of the exhaust port. In contrast the hookah rig employs a demand system, with air flowing only when the diver inhales. The 90m-long hardhat umbilicals were made up of three lines: the air supply line, the communication wire, and the kluge which is an open-ended hose leading to the depth gauge on the dive panel. The umbilical also served as a safety line; being strong enough to enable divers to be pulled to the surface in an emergency.

There were three air supply sources to the dive control panel; two 86cfm electric low pressure compressors and a six bottle high pressure quad. Only one low pressure compressor was used at a time; the other served as a backup when the first required maintenance. The high pressure supply was for emergencies such as a power failure during a dive. The redundancy feature of the air supply system was effective and only about 15 minutes of diving time during ten months and over 10,200 dives was lost due to equipment failures.

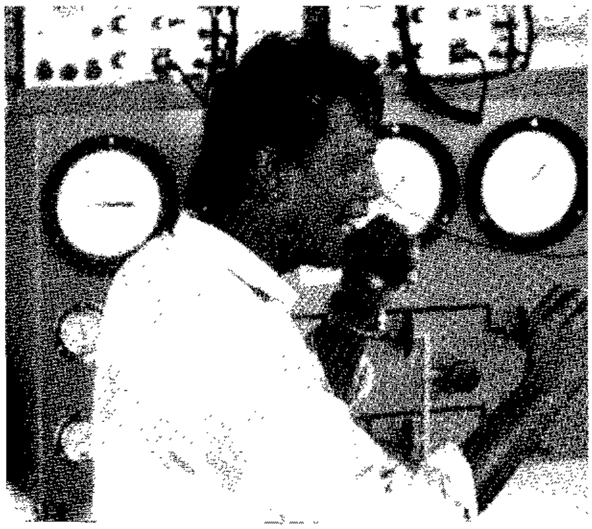
The same compressors and a separate control panel were used to run the *Tengar's* Galeazzi diving bell. This three-person bell was fitted with four large ports for reasonable all-around viewing. The bell was suspended from *Tengar's* 12-ton crane and could be operated in two modes: first as an observation chamber, and secondly as a lock-out bell. In the observation mode, the bell could be lowered to 75 meters. However, the one atmosphere pressure inside the bell allowed the divers to stay down for as long as

SCUBA diver entering the water

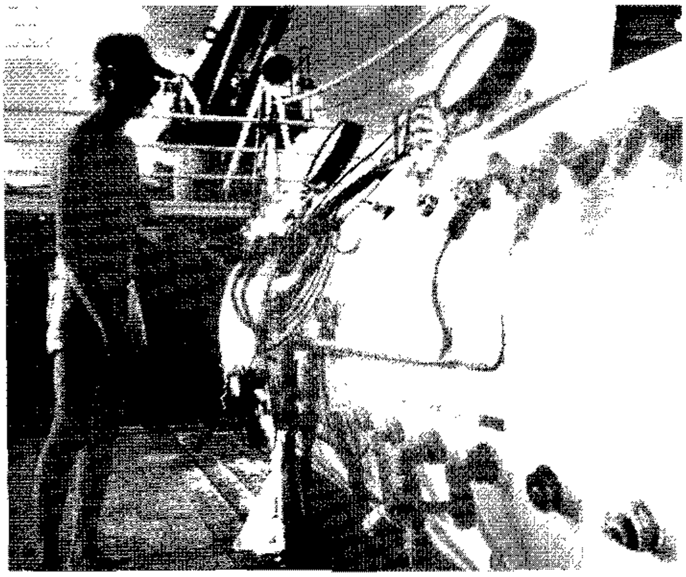
Hookah divers clearing blocked eductor discharge hose during removal of coral rubble and sediment overburden in 6 meters of water

Hardhat diver excavating overburden with 150 mm airlift

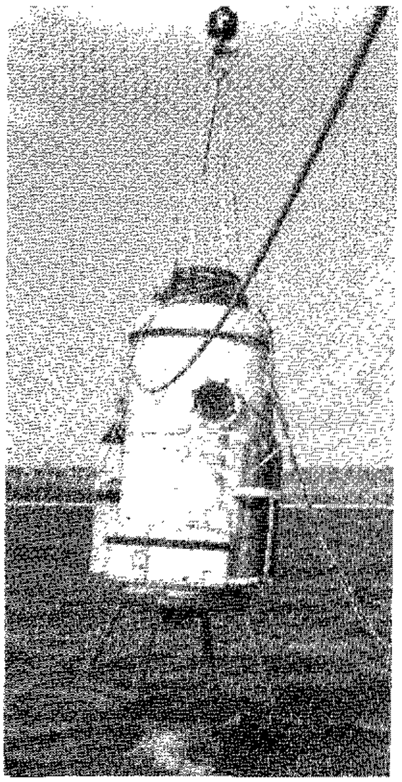
Pre-dive briefing by archaeologist Amanda Crowdy during predisturbance survey



Dive coordinator Jumnian Ruenrawat communicating with hardhat divers



Team diving instructor Bill Spurlock routinely testing recompression chamber onboard recovery vessel



Diving bell about to be lowered to seabed in 70 meters of water necessary without needing decompression. The bell was fitted with a carbon dioxide scrubber, an oxygen analyzer, and external oxygen bottles to make up the oxygen level should it fall below optimum range.

To operate in the lock-out mode, the bell was blown down to the ambient pressure of the sea water using surface air supply or alternately, by using the bell's external H.P. air bank. When ambient pressure was reached, the bottom was opened allowing divers to leave the bell. When divers returned to the bell, the internal hatch was shut and the bell was lifted to the surface. Once back on board, divers could complete decompression inside the bell in relative comfort and safety.

The *Tengar* was also equipped with a fifty-two inch diameter double-lock steel chamber connected directly to the electric air compressors in a constant state of readiness. Two divers breathing oxygen could be accommodated comfortably in the inner lock; however, if the need arose, four divers could be treated on oxygen at once. The *Tengar*'s recompression facility was the only one within 120 miles. It was tested weekly to ensure that all systems were always in working order.

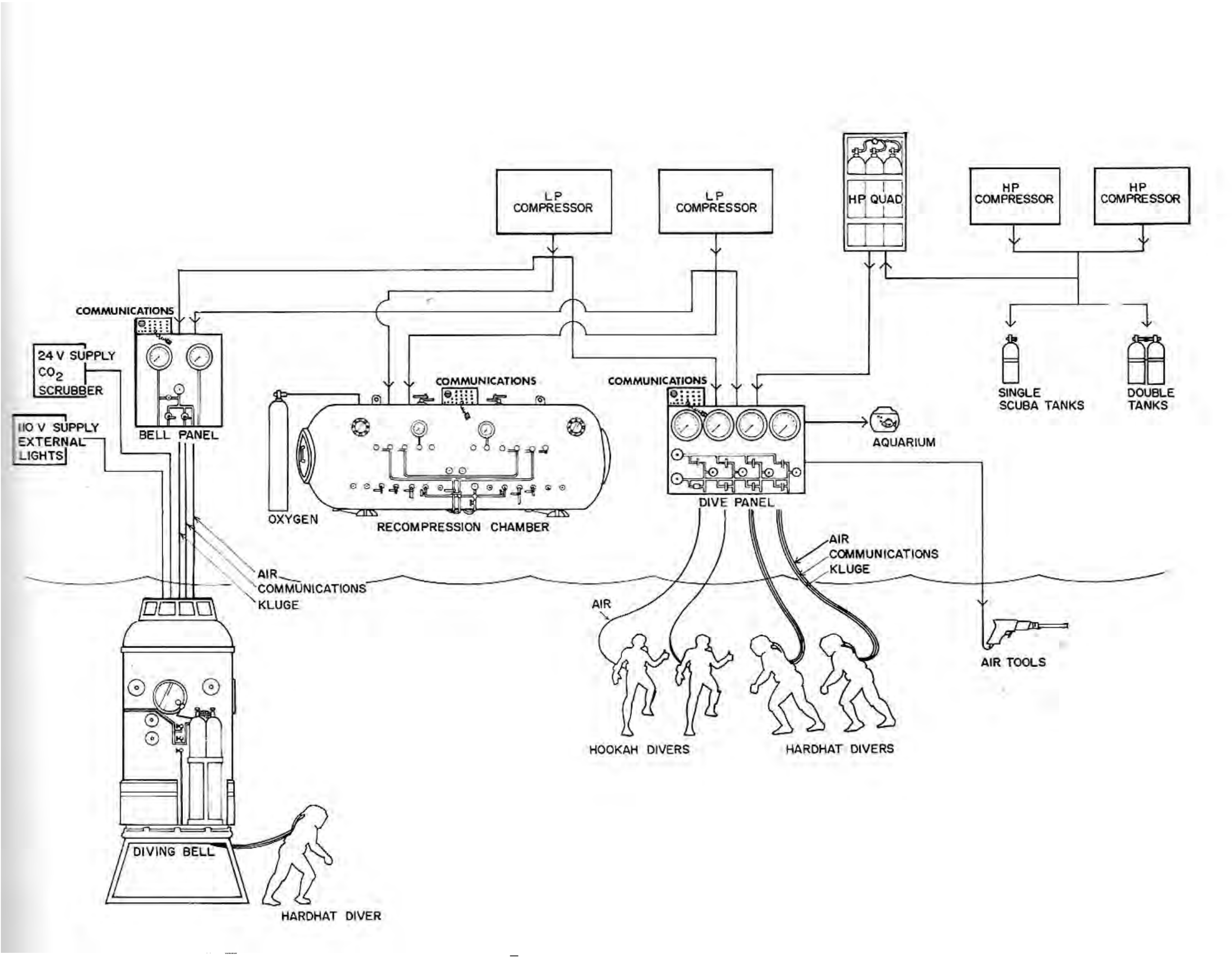


Figure 6

EXCAVATION TECHNIQUES

Excavation techniques and tools included hand fanning, airlifts, lift bags, water eductors, water jets, a prop thrust deflector, a variety of pneumatic and hand tools, and boulder lifting gear.

For excavating small areas of sand and light coral rubble in 10 to 15m, airlifts worked reasonably well. PSR used airlifts ranging from 50mm to 150mm in diameter. However, airlifts lose efficiency in very shallow or deep water and, being vertically aligned, they tend to dump material on top of the operator and the site in an uncontrolled manner. This greatly reduces visibility and distributes harmful sediments over the reef. Airlifts are also difficult to control when a blockage occurs.

Because of the disadvantages of airlifts, PSR primarily employed water eductors. A high pressure water jet nozzle would create a flow that effected a larger flow of water that could vacuum up sediments and deposit the spoil 3 to 12m away. For minor excavations, PVC 100mm eductors were employed which were powered by portable 50mm diesel pumps. The eductors could be deployed from the tenders in depths as shallow as 1m on top of the reef, or in 65m around the deep water storage jar concentration, working just as efficiently in both locations.

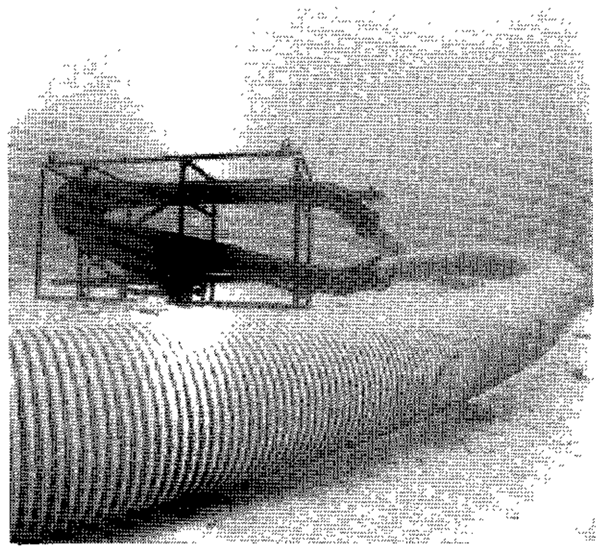
In order to tackle the large volumes of coral rubble and sand, including deposits in the gullies, PSR designed and built 250mm water eductors. Several designs and materials were tried. A stainless steel eductor with a heliacally reinforced clear plastic discharge hose and a PVC thrust deflector proved to be the most effective. The *Tengar*'s 800 GPM fire monitor pump supplied water via a 100mm high pressure hose through a manifold to 50 and 75mm hoses connected to the eductors. Up to five eductors of various sizes could be in use at once. The 250mm eductors were powerful, capable of vacuuming coral rubble up to 200mm in diameter from the seabed and depositing them 12m away. Despite their size and power, the eductors were easily handled by divers as the water flow was readily controlled and blockages were relatively simple to clear, making the eductors most suitable for both delicate excavation and the movement of masses of overburden. Delicate work was accomplished by placing the suction head about half a meter from the work face and hand-fanning sediments toward it.

PSR also used 150 and 200mm eductors, constructed of rigid PVC or stainless steel, with flexible plastic hose discharges. The underwater valved manifold permitted a quick change of eductors as dictated by the terrain; 250mm eductors were used for wide gullies with deep overburden, and the smaller models were employed for narrower, twisting gullies and crevices.

Ancillary excavation equipment included water jets, a bow thruster deflector, and boulder lifting gear. The water jet could either be connected to one of the 50mm pumps or to the eductor manifold. It was fitted with a retro-jet to neutralize thrust and was used primarily to blow away shallow sand deposits in order to closely examine irregularities in the seabed.

To remove areas of shallow overburden in depths up to 6m, a bow thruster deflector was fabricated. This 2m-diameter steel cylinder deflected the horizontal thrust of the bow thruster through 90 degrees towards the seabed. Divers attached the deflector to the thruster tunnel with turnbuckles. However, this deflector was seldom used, as the eductor systems were found to allow greater control in excavation.

The boulder lifting gear consisted of a system of chains, chain hooks and lift bags (100, 500 and 1,500kg). Boulders that were too large to shift with crowbars could usually be lifted clear with the lift bags. Air for the lift bags was supplied by a hose from the dive panel or from a SCUBA tank.



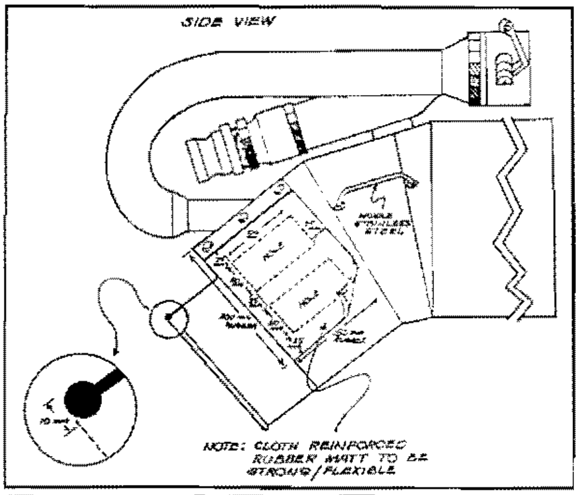
Underwater device to separate sediments according to size, with selected materials transferred to surface sorting and screening tables

Hookah diver using pneumatic chipping hammer to remove concretion in 8 meters of water

SCUBA diver, in 70 meters, securing storage jar for lifting to surface

Hardhat divers removing coral boulders in search of buried artifacts in 15 meter depths

Hookah divers using 250mm eductor to remove gully sediments



One of the 250mm eductor fabrication drawings

Diver Corey Malcom holding gold chain located on weathered coral bedrock

SCUBA diver investigating crevices with 100mm eductor in 18 meters of water

COMPUTER SYSTEMS AND DATA PROCESSING

An important aspect of PSR's archaeological recovery of artifacts from the *Concepción* was the entering, storage and manipulation of artifact information. A complex, computerized data recovery system coordinated the three different components of the documentation process. These components were: the acoustic positioning system which allowed each artifact's coordinates on the seabed to be determined and plotted, the image capture system which supplied visual images of artifacts in situ and during various stages of processing onboard the recovery vessel, and the artifact data processing center for filing archaeological, conservation, appraisal and image data. (*Figure 7*). The hardware and customized dBase III compatible software allowed flexibility in generating reports and combining text with visual information.

The combined image capture and database files allowed artifacts to be sorted by artifact number, location, material, or any other input criteria. Individual artifacts could be called up instantly, with it being possible to scroll a display of the artifact's full written description plus all the images taken. This simple data manipulation facilitated the archaeologist's task of deducing further information from the artifacts.

The main components of PSR's computerized data recovery system were IBM compatible and Zenith laptop personal computers, Sony CCD chip cameras for underwater video, and Panasonic CCE chip cameras for laboratory documentation. The image capture system was based on an AT&T Truevision board and an AT&T Targa 16 board, both fitting into standard ports on an IBM compatible personal computer, together with a video monitor and a video camera capable of transmitting to the image capture board. Live images and images retrieved from disk were also displayed on the color monitors. Both systems had camera attachments to allow either 35mm or Polaroid pictures to be taken of the images.

The image capture system was designed for video input. After adjusting the camera to obtain the optimum image, a single keystroke captured the image and stored it on the computer. One video input was used to capture images taken onboard the *Tengar*, such as still pictures and conservation procedures, while the second input came from the CCD underwater video camera. In addition to archaeological recording, a professional film team was on site for a good part of the recovery period and they recorded field operations for documentary films and for future addition to the database.

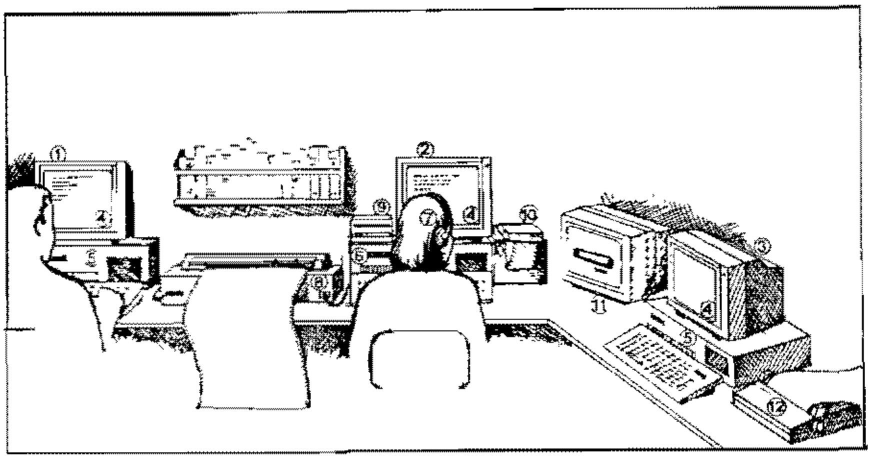
The software generated for the *Concepción* project included four database files: archaeology, conservation, appraisal, and images; the records within these files were referenced by artifact number. The archaeology files included but were not limited to the following information for each artifact; the location of the find, name classification, material type, condition, weight and context. The archaeological data was hierarchical in nature, with the classification system set up to evolve with the finds. For example, the decreasing hierarchal classification of a gold button would be class jewelry, subclass button, and type A button. And if type E was a new category of button, the program would save this name, noting that it was a subcategory of jewelry and button, and store the new description. The structure of the Artifact Database is included in Appendix B.

Data in the conservation files described the procedure used to conserve each artifact. During conservation, the same sequence of procedures was applied to artifacts of the same material type. The program was designed to take a user specific sequence code and prompt for the date and duration of each of that sequence's procedures. A single artifact could undergo as many as eight conservation related procedures, including examination, chemical cleaning, mechanical cleaning, rinsing and drying.

The appraisal file contained information on the estimated value of each gold artifact, as provided by appointed officials from Sotheby's of London. This was done for insurance and shipping purposes.

The image database file included the artifact number, image file name, and a short description of the artifact's orientation during image capture; some artifacts have several image files associated with them. When an artifact file was retrieved, pertinent information, as from one of the other database files, could be displayed with the image(s) on the color monitor.

The system worked reasonably well, as it was robust enough to withstand the shipboard environment of sudden power outages, saltwater air, rolling motions of up to 40 degrees and humidity. It also utilized a redundancy of components to combat the problem of a lack of readily accessible computer spares. The project specific user's manual, combined with a menu driven format, allowed for maximum operation by crew members, several of whom were not previously computer proficient.



ARCHAEOLOGICAL DATA PROCESSING CENTER

1. Artifact/Conservation Data Entry Workstation
2. Underwater Workstation
3. Computer program development workstation
4. Thompson 250G monochrome display
5. Dellfield 286 enhanced PC-XT with RS-232 cable for inter-workstation communications
6. Dellfield 286 enhanced PC-XT with Truevision image capture board, RS-232 cable for communications with image capture workstation
7. Headset used for audio communication with Image Capture workstation
8. Epson LX 105 printer
9. [illegible] optical disk
10. Polaroid Freeze Frame Video Image Recorder with Autofilm back
11. Sony KX-14CPI color monitor
12. Epson LX-86 printer

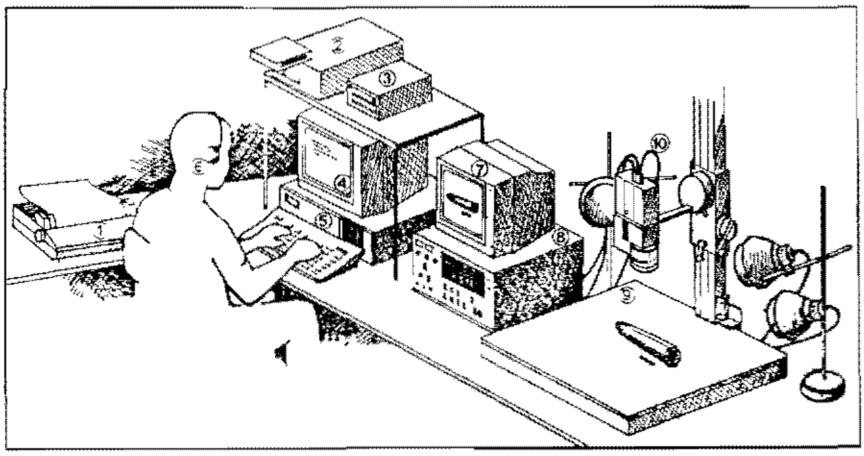
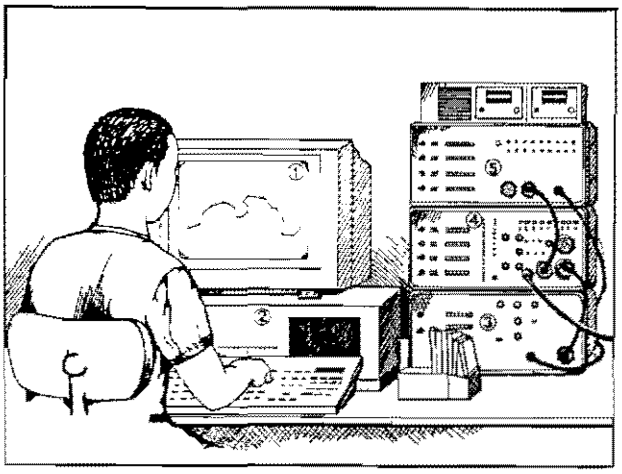


IMAGE CAPTURE STATION

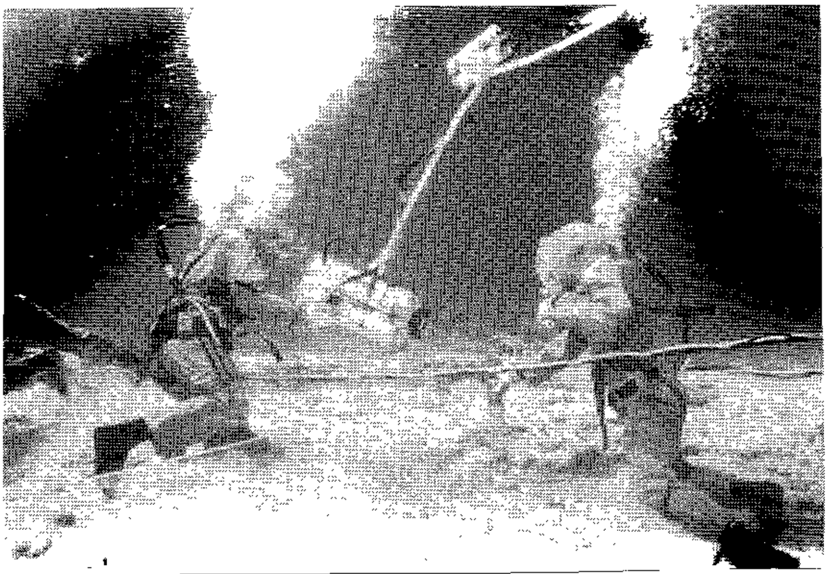
1. Epson LX-86 printer
2. Polaroid Freeze Frame Video Image Recorder with AutoFilm camera back
3. Maxtor PC-500 optical disk drive
4. Thompson 250G monochrome display
5. Dellfield 286 enhanced PC-XT with Truevision TARGA image capture board, RS232 cable for communication with underwater workstation on bridge
6. Headset used for audio communication with underwater workstation on bridge
7. Sony KX-14CPI color monitor
8. Sony VO-5600 3/4 inch video recorder
9. Camera stand with lighting
10. JVC-870K - RGB video camera



ACOUSTIC POSITIONING STATION

1. Thompson 250G monochrome display
2. Dellfield 286 enhanced PC-XT
3. Oceano Acoustic Module AM123 transmits and receives signals from underwater transponder
4. Oceano RM203 rangemeter control panel
5. Oceano Central Processing Unit for computer controlled measurement

Figure 7



Transferring video images of artifact in situ to onboard image capture system and locating the artifact with an acoustic positioning system transponder held by the diver

Image capture system in computer room aboard the recovery vessel being operated by programmer Martin Hall

Martin Hall operating image capture station in conservation laboratory on board M/V Tengar

ARTIFACT REGISTRATION AND HANDLING

An essential facet of the systematic excavation of a shipwreck is the registration of the cultural materials recovered from the site. In light of this, PSR followed a detailed procedure for the recovery, treatment and handling of artifacts. *Figure 8* shows the stages of processing for an artifact. On finding an artifact, the diver often used an acoustic positioning system to ascertain the location and an underwater camera (video or still) was used to film the find in situ.

As soon as the artifacts arrived on deck, all readily determined information such as sequentially assigned artifact number, date, diver, location, context, seabed features, and general artifact description such as color, condition, material and category, if known, was entered manually into the Finds Register (*Figure 9*). This was simply a log book with the same format as the computer database, kept at the on-deck registration desk. The entries were chosen from a standardized "menu" of codes for each of the qualities being addressed. At the end of each day, the log was photocopied for data entry into the computer database the next morning. The computer database was the final, permanent version of the log.

After the information was entered into the Register, the artifact was taken to the conservation laboratory for cleaning, weighing, measuring, conserving and/or stabilizing, further classification, preliminary appraisal and eventually storage. The entire conservation process was entered into the conservation database along with images of the artifact, either photographed (with a 35mm camera and or the computer's image capture system) or illustrated. At least one example of each artifact was drawn by an archaeological illustrator on site, as drawings of this nature often show more detail than a photograph. This assured that a visual record of each artifact type would be available in the database. All databases were updated as necessary.

A printout was made of the database for every 100 items entered into the system and edited for entry errors. The length of time to incorporate all pertinent information into the database was primarily dependent on how long it took to clean and conserve the item. This was especially problematical for corroded or encrusted objects; until the encrustation or corrosion products were removed or stabilized, the details of the artifact could not be sufficiently determined for classification, nor could accurate weights, dimensions or drawings be obtained. For certain items, it took many months before all pertinent information was entered into the database.

Not all recovered artifacts were individually registered. Ceramic shards and fragments of lead sheathing from the *Concepción* were grouped in bulk according to the collection zone, and the bulk grouping received an artifact number. The ceramic artifacts were divided according to typology: the earthenware and stoneware shards were classified according to materials and function. The small size of the porcelain shards prohibited determination of function until later specialist study, and thus classification for these shards was based on design alone. All shards were labeled with identification numbers affixed with layers of enamel, india ink or printing pen, enamel and then packed in small polyethylene bags for storage.

The system of artifact registration employed by PSR was efficient, relatively simple to implement and adequately descriptive; containing the raw data needed for comparative analysis of either inter- or intra-site collections. It was a system that facilitated the quick retrieval of data and allowed for easy amendment to the files.

After recovery and initial stabilization/ conservation, the artifacts were insured according to preliminary appraisals conducted onboard the *Tengar* by designated officials from Sotheby's and Christie's, with both PSR and the CNMI government named as the assured in accordance with their percentages of ownership. The artifacts were then carefully packed and transported to the appropriate institutions for the completion of conservation treatment, restoration, specialist study, and final appraisals. An inventory record of all conservation files accompanied the artifacts for use during the final conservation and restoration process. Final artifact appraisals were carried out in London by directors of Christie's. Restoration work was completed by Antique Jewelry Restoration Laboratories in Singapore and the British Museum in London.

ARTIFACT PROCESSING PROGRAM

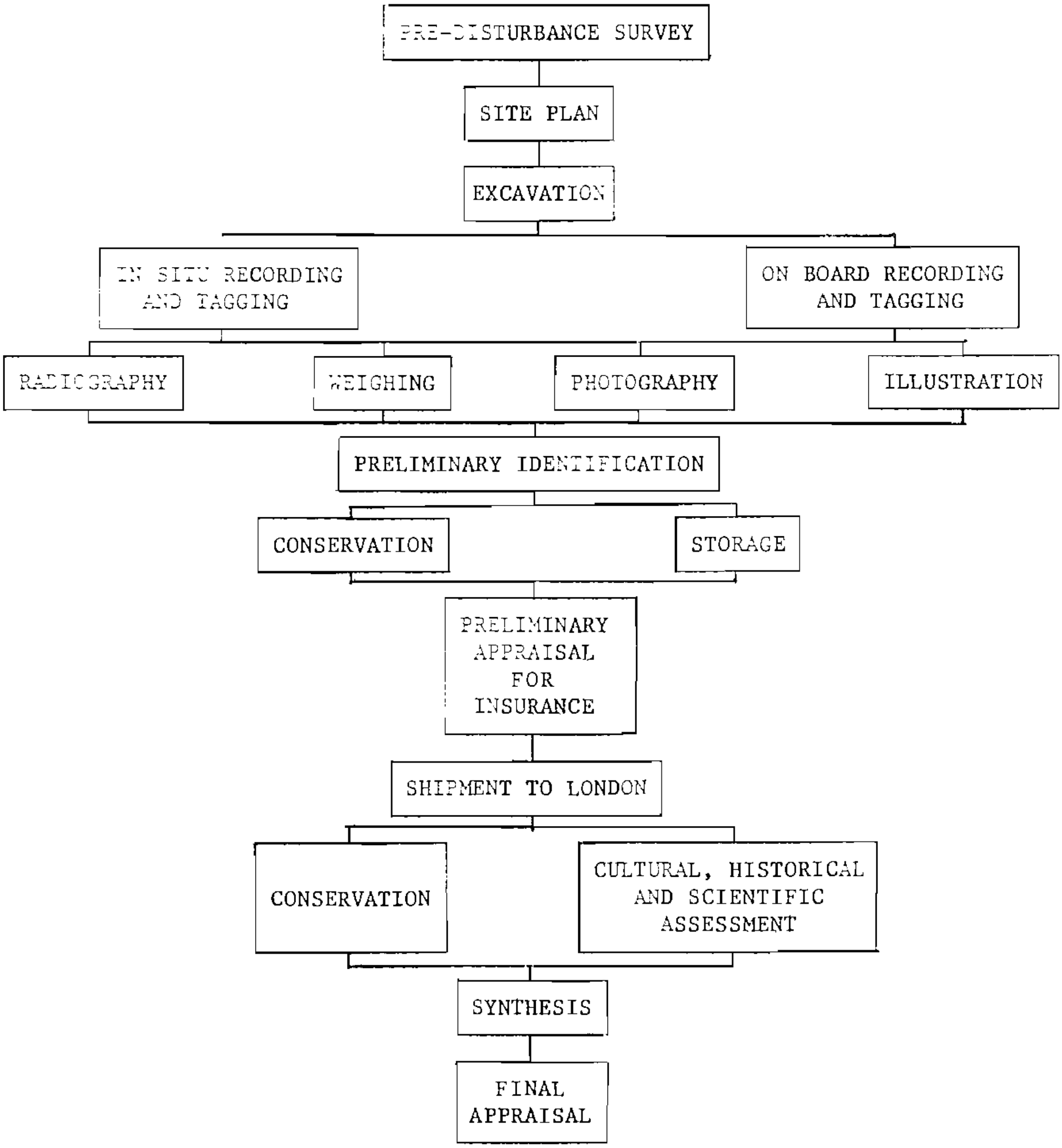
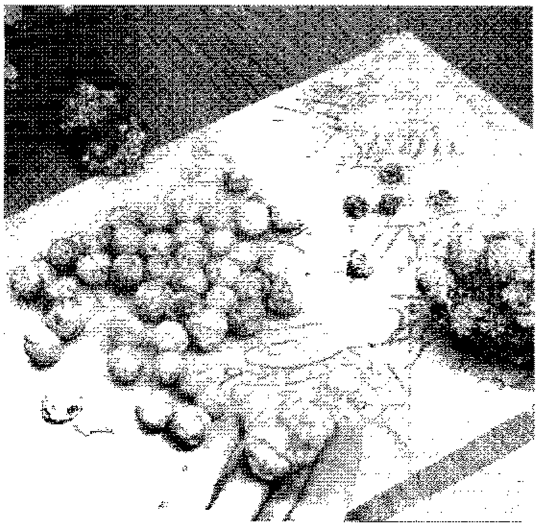


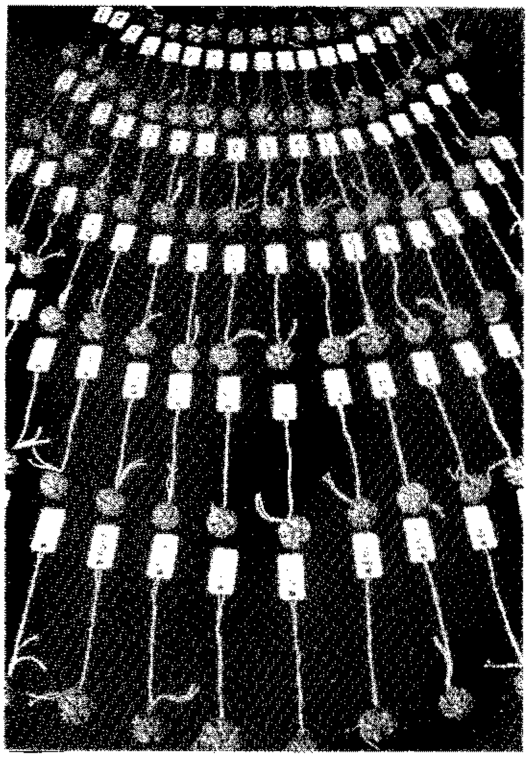
Figure 8

Artifact information being logged into Finds Registration book by archaeologist Amanda Crowdy and deputy project director Hank Parker



Lead arquebus and musket shot recovered from gullies on top of divers' location chart

Artifact locations being drawn onto the master site chart by marine superintendent Nutty Carr, and project artist and deep diver Marilee Krinitt



Some of the gold filigree buttons with their artifact numbers attached

Figure 9

ARTIFACT CLASSIFICATION SYSTEM

GOLD JEWELRY

- Diamond Ornaments
- Ornamental
- Ornamental Openwork
- Filigree
- Crosses
- Rings
- Belt Ends
- Higa
- Flat-Backed Buttons
- Flat-Backed Buttons with Diamonds
- Small Buttons
- Spherical Buttons
- Spacer Beads
- Complex Chain
- Simple Chain
- Gems
- Miscellaneous

SHIP'S STRUCTURE

- Wood
- Rope or Cable
- Bolt
- Spike
- Tack
- Lead Sheathing
- Miscellaneous

ORDNANCE

- Cannon
- Cannonball
- Musket Shot
- Arquebus Shot
- Sword
- Miscellaneous

CERAMICS

- Porcelain
- Storage Jar
- Miscellaneous

SHIP'S GEAR

- Sounding Lead
- Anchor
- Miscellaneous

SPECIE

- Spanish Coin
- Chinese Coin
- Miscellaneous

PERSONAL EFFECTS

- Chinese Weight
- Bobbin
- Brass Button
- Sword Buckle
- Sword Clasp
- Miscellaneous

DOMESTIC ITEMS

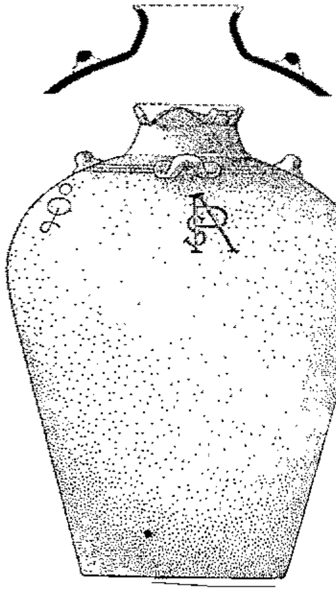
- Spoon
- Fork
- Bowl
- Candle
- Key
- Lock
- Miscellaneous

JAR CONTENTS & CARGO

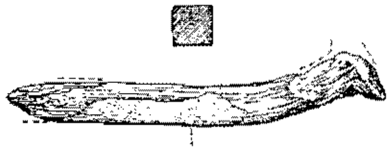
- Bone
- Resin
- Stone
- Pepper
- Glass Beads
- Dome Buttons
- Square Buttons
- Dome Furniture Tack
- Tiered Dome Furniture Tack
- Star Furniture Tack
- Miscellaneous

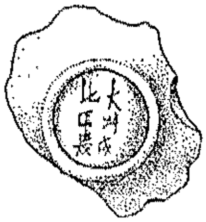
MISCELLANEOUS

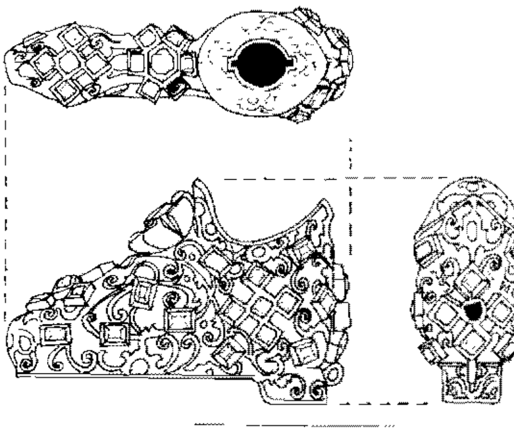
- Storage Jar Lid
- Ballast Stone

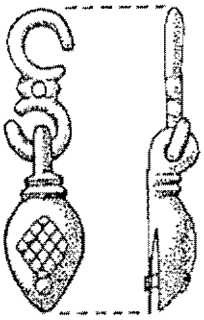


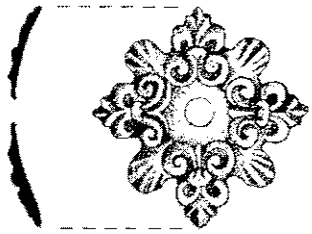
Archaeological illustrator Eduardo Bersamira tracing inscription on storage jar onboard recovery vessel Tengar; typical archaeological illustrations of recovered artifacts

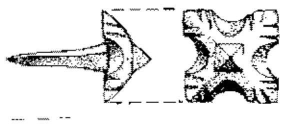


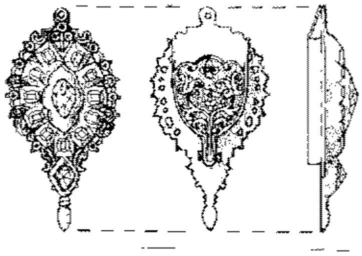


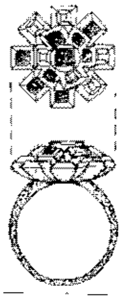


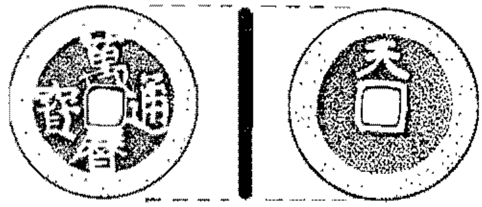










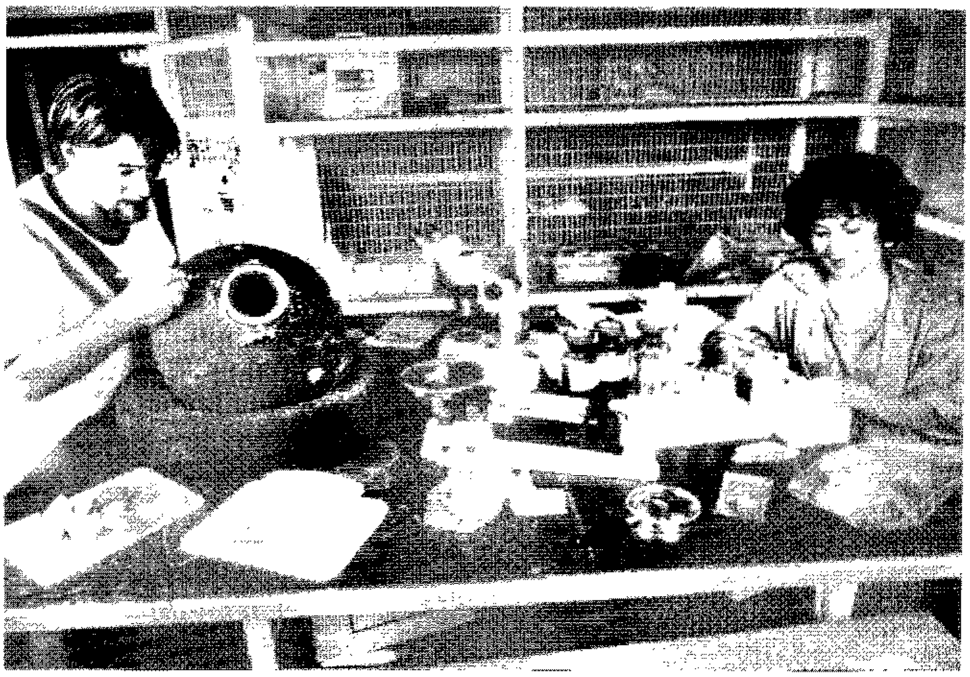


CONSERVATION PROCEDURES

PSR maintained an onboard conservation laboratory because materials which have survived in a burial environment for hundreds of years have usually reached a state of near equilibrium with their surroundings so that the rate of deterioration is very slow or insignificant. Removal from the burial environment disturbs that equilibrium and the chemical processes of decay may again become active. Unless care is taken, the recovery of material from shipwrecks could result in rapid corrosion of metals, flaking of pottery and disintegration of other materials. The chemical stabilization of recovered artifacts requires the immediate intervention of experienced conservators. The *Tengar's* conservation laboratory, staffed by two trained conservators, provided conservation treatments required for stabilizing and protecting materials recovered from the *Concepción* wreck site.

The onboard conservation team had four priorities. The first was artifact stabilization or placement of finds in a corrosion inhibiting environment. Artifacts were monitored periodically to ensure continued effectiveness of the chosen storage medium. Secondly, each artifact's condition upon recovery and method of stabilization was documented. The third priority was to initiate appropriate treatment procedures within the previously mentioned constraints. The final step was to ensure that adequate measures were taken for the packaging and shipment of an artifact for final restoration and preservation in a land-based laboratory in Singapore or London.

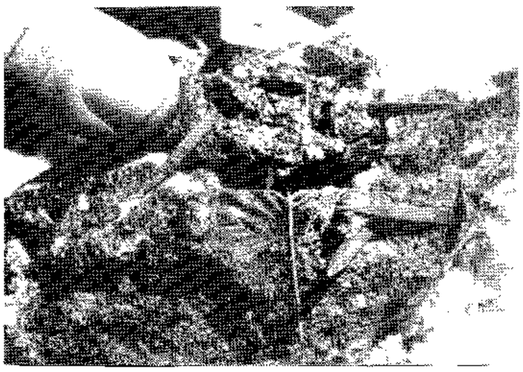
The *Tengar's* conservation laboratory, located in the 54 square meter starboard hold, was outfitted with the supplies required for extended storage of marine artifacts as well as selective conservation procedures including electrolytic reduction, mechanical and chemical cleaning, chemical drying and coating, stabilization, and restoration. Equipment included low power binocular microscopes (20x and 10x), pneumatic scribes and drills, an ultrasonic cleaner, conductivity meters, etc.



Conservators David McIntosh and Myrna Clamor working in conservation laboratory on M/V Tengar

Radiographic examination of concreted or composite objects was carried out in a hospital laboratory in Saipan. This enabled identification of encrusted objects before active conservation. A cascade system allowed objects to be washed in fresh water with regular monitoring of chloride level. A number of tanks of varying sizes accommodated the objects needing to be kept in solution.

Project director Bill Mathers and conservator David McIntosh examining x-ray of concretion



Close up of section of concretion

Treatment records were entered into a computer within the laboratory. The conservation database was invaluable for documenting procedures, monitoring chloride levels, and particularly for referencing in the event that further conservation or restoration would be performed elsewhere on the artifacts. Initial conservation of artifacts recovered from the *Concepción* site began immediately following registration in the finds log. Complete conservation of some materials on site was not possible because of space, equipment, time, and control restrictions. For many artifact types, on-site treatment was restricted to storage in an appropriate medium, while for others more extensive conservation was undertaken.

Artifacts were classified into the following groups for conservation purposes: metals (gold, copper alloy, silver, lead, and iron); ceramics (earthenware, stoneware, and porcelain); glass; and organic material. The stabilization and treatment procedures selected were appropriate to artifact material.

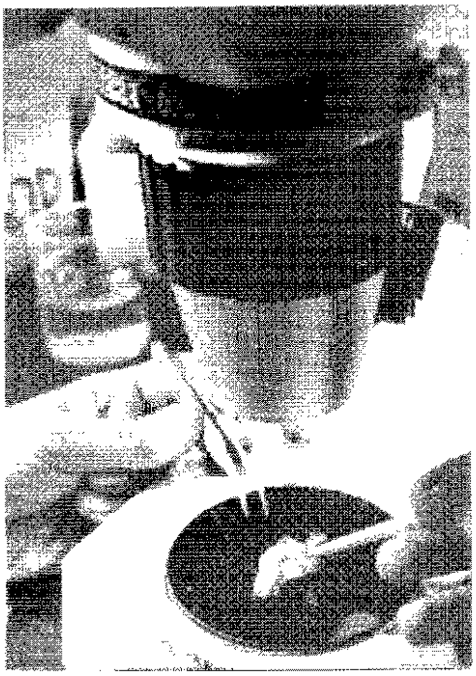
STEP 1: DOCUMENTATION

Onboard documentation of objects recovered consisted of some or all of the following: initial examination results, photographs, illustrations, image capture, radiographs, treatment procedures, results and recommendations, and data entry into the computerized archaeological database. Obviously the degree of documentation depended on the nature and condition of the recovered object. Initial examination was carried out through visual inspection (normal and microscopic), mechanical cleaning and, less frequently, chemical testing for material identification purposes. The results determined the most appropriate treatment methods, stabilization, and storage procedures for that particular artifact. This information was then recorded on a material specific conservation form and was later transferred to the conservation files in the computerized database.

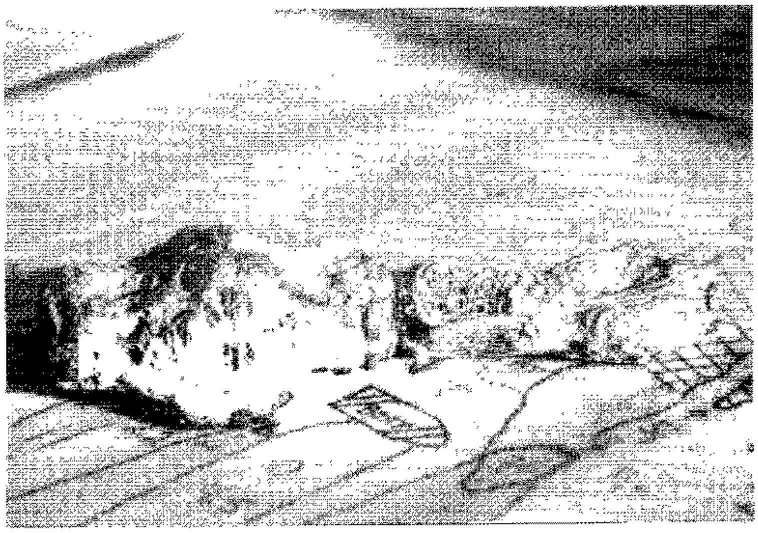
STEP 2: STABILIZATION AND TREATMENT

A. METALS -- Gold

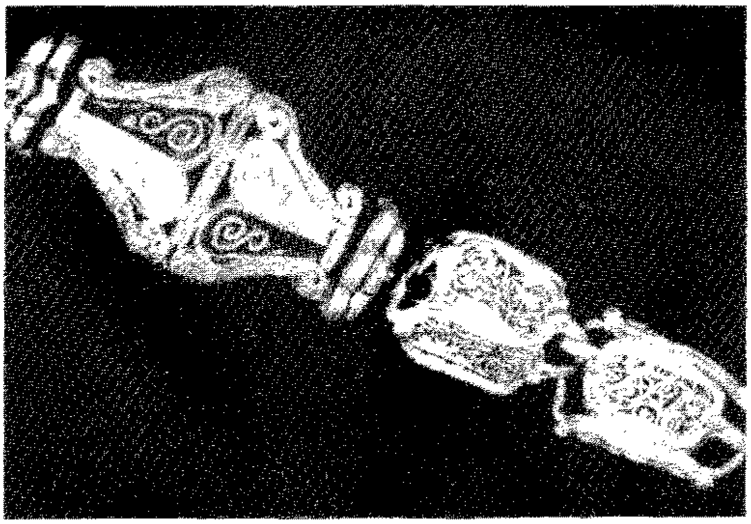
Examination of gold artifacts recovered from the *Concepción* site resulted in the development of two separate treatment sequences, one for objects made solely of gold, the other for objects consisting of gold and other



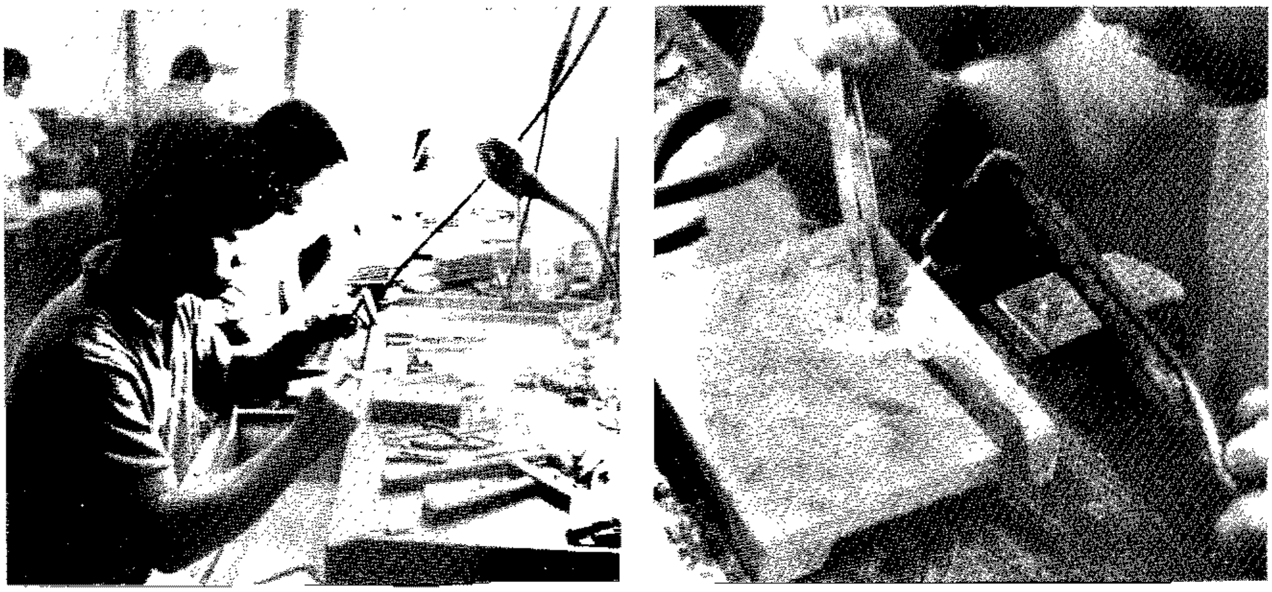
Section of gold plate being cleaned of coral encrustation and stains under microscope



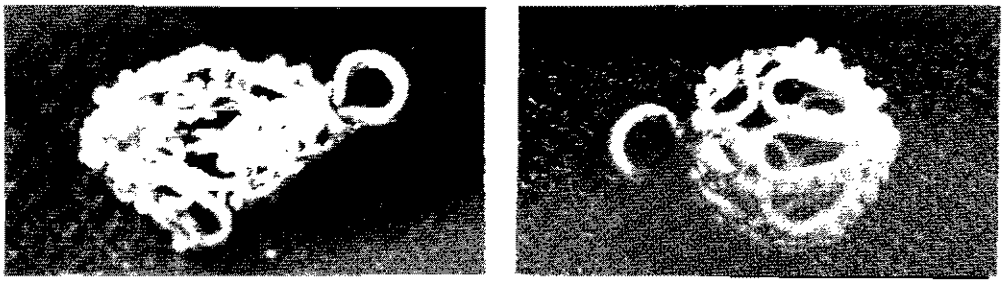
Chain and pendant upon recovery from beneath the loose coral and sands



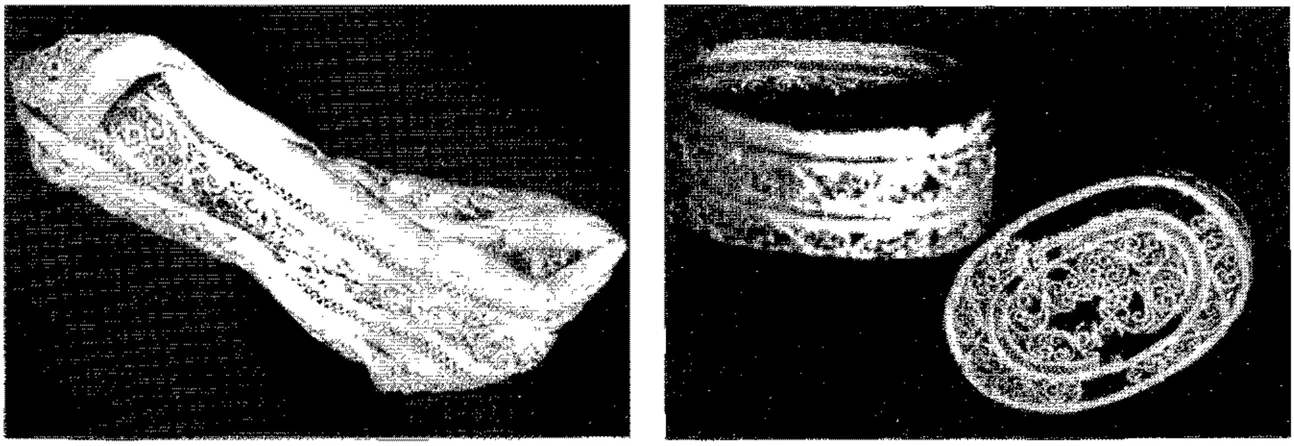
The above artifact after conservation processes in the laboratory



Goldsmiths restore damaged gold jewelry artifacts in the workshop of Antique Jewellery Restoration Laboratories in Singapore



Damaged gold button before and after restoration



Crushed gold basket after chemical removal of calcareous growth; the same basket and its top after restoration material; normally a precious stone. Prior to conservation, most gold objects were encased in a partial or complete calcareous encrustation and usually were dented, fractured, flattened or fragmented. All pieces were cleaned on-site, usually within 72 hours of recovery. No attempts at on-board restoration were made, this being left for experienced goldsmiths in London and Singapore.

Artifacts made solely of gold included spherical filigree buttons, complex filigree chain, simple link chain, impressed or cast plateware, and unidentifiable jewelry fragments. These and similar items were freed from gross encrustation through immersion in a fifteen percent formic acid bath. Small remaining bits of coral and algae were removed by ultrasonic cavitation at approximately 40 degrees Centigrade in a fifteen percent stock jewelry cleaning solution. The cleaning solutions were subsequently removed through ultrasonic cavitation in fresh water. Finally, the artifacts were dried through immersion in acetone, and then placed in polyethylene bags for storage, each containing tags with artifact numbers.

Gold pieces set with precious and semi-precious stones or glass, as well as pieces with enamel inlays, included examples of finely crafted hand-made jewelry in the form of rings, pendants, chains and buttons. Precious stones recovered consisted of diamonds, rubies, emeralds and a sapphire. Semi-precious stones have been tentatively identified as quartz. Encrustations on stones were removed by mechanical cleaning under a microscope (at 20x and 40x). Effective cleaning tools included a dental pick, scalpel, and thin paint brush. Gold pieces were corrosion-free due to that metal's stable nature in a sea water environment. In rare cases, the gold was discolored. The discoloration has been tentatively identified as a surface film of iron oxide or sulphide, probably deriving from modern and contemporary iron deposits found near and sometimes in contact with the affected pieces.

METALS -- Copper

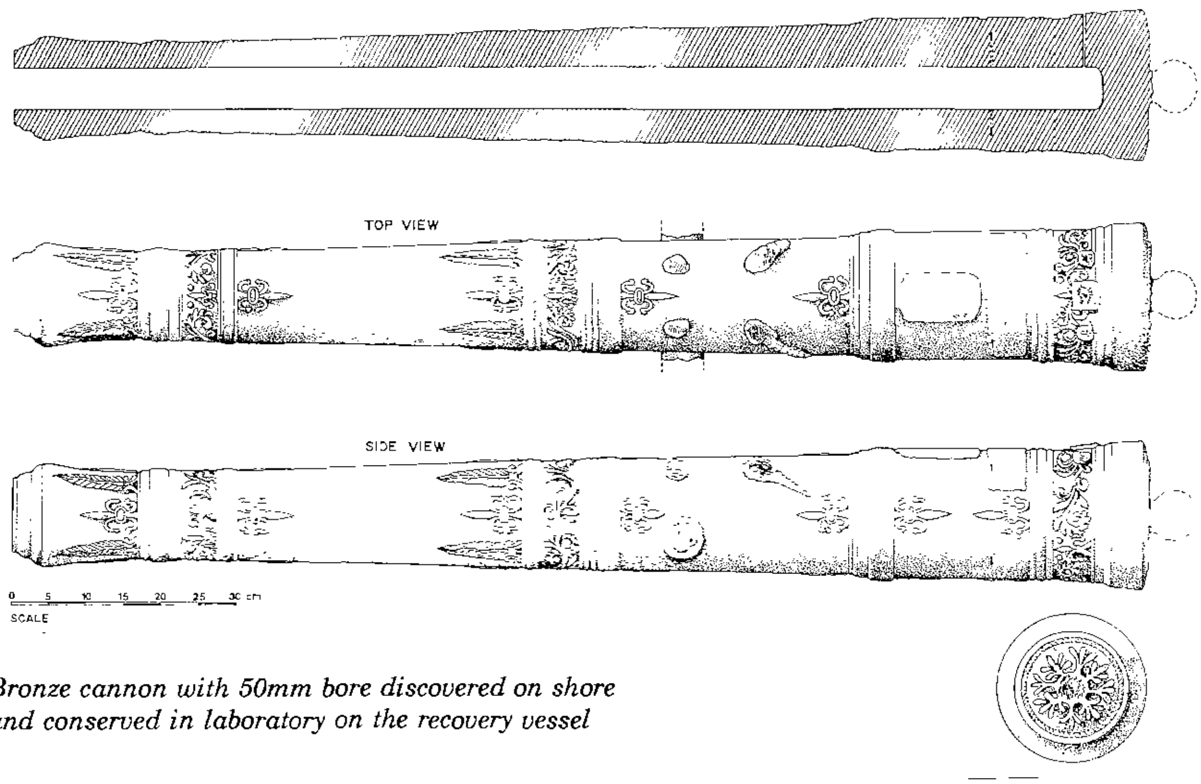
In excess of one hundred alloy artifacts were recovered from the site. Upon arrival in the laboratory, copper-based objects were dried and placed in an unsealed polyethylene bag which was then stored in a sealed, plastic tub containing silica gel, which was periodically renewed as required. The desiccant absorbed the moisture from the sealed atmosphere thereby preventing the formation of basic cupric chloride, or "bronze disease." Where chloride deposits had built up, they were removed either by electrolysis or sodium sesquicarbonate baths. The treatment choice was generally based on two criteria: the amount of solid metal remaining in each artifact and the presence or lack of an aesthetically pleasing patina.

Many bronze objects recovered from the *Concepción* site had a solid metal core as well as an attractive patina, such as large scalloped clavoses, handles, pestles and a cascabel. Immersion in a five percent solution of sodium sesquicarbonate was chosen as the method of chloride removal for these and similar items. Although this process involved a relatively long treatment time, it was quite effective for removing chlorides while still retaining the patina.

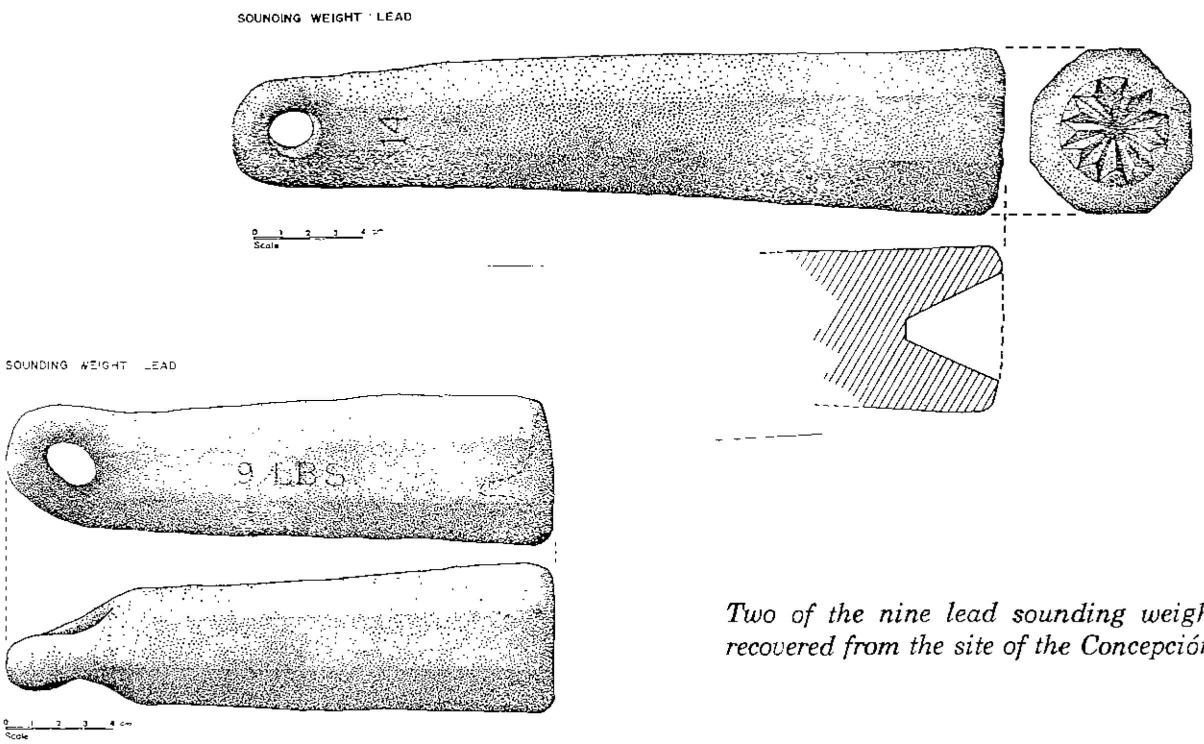
Other bronze objects treated by the sodium sesquicarbonate method included complete Chinese coins and numerous unidentified fragments. The coins had a relatively solid metal core but lacked a complete patina; therefore, electrolytic reduction was considered as the means for chloride removal. However, subsequent microscopic examination revealed slightly raised Chinese characters on several of the coins. It was determined that the characters consisted of little more than cupric carbonate, so in order to preserve them, sodium sesquicarbonate was selected for chloride removal rather than electrolysis. This method was chosen because a sometimes unfortunate result of electrolysis is that an artifact is stripped of all corrosion products leaving only bare metal. Despite the treatment method, the desired result was to be the same: removal of chlorides from the remaining metal and corrosion products followed by stabilization with a corrosion inhibiting coating.

METALS -- Lead

Lead artifacts were stabilized by rinsing in fresh water and storing in polyethylene bags. Most of the pieces were later placed in electrolysis, using a ten percent solution of sulfuric acid as the electrolyte, for three hours at a current density of 5.5 amps/square dm. The carbonates and algae were then removed revealing on two of the sounding weights, the inscriptions "9LBS" and "14LBS".



Bronze cannon with 50mm bore discovered on shore and conserved in laboratory on the recovery vessel



Two of the nine lead sounding weights recovered from the site of the Concepción

Iron artifacts were stored in a solution of two percent sodium hydroxide or five percent sodium carbonate following recovery. Solution levels were checked once a week and replenished when necessary prior to shipment. A dozen small items, including spikes, cannonballs and the end of a grappling hook, were placed in electrolysis using an electrolyte of two percent sodium hydroxide at a current density of 5.0 amps/square dm. Qualitative tests for chlorides were made on a weekly basis with the solution being changed once a month.

Other iron-based artifacts from the *Concepción* included degraded spikes encased in coral. These encrustations were cleaned out with dental pick, scalpel and small water jet, then cast with Smooth-On 200.

The most challenging conservation task was the stabilization and treatment of a 1.9-ton iron anchor from the *Concepción*. A large waterproofed plywood tank was built to accommodate the anchor in a fresh water bath (*Figure 10*). The anchor then underwent two months of electrolysis, after which encrustations were mechanically removed by tapping perpendicular to the anchor surface. The anchor was then immersed again in the electrolysis bath where it remained until chloride tests signified that electrolysis was complete.

On completion of electrolysis, the remaining encrustation was carefully chipped off with a hammer and chisel. The metal surface was then wire brushed by hand, washed with denatured alcohol to remove surface moisture, and finally coated with a zinc rich surface preparation. Twenty-four hours later the surface was checked for any signs of oxidation and two coats of organic zinc primer were applied, the top two coats being black epoxy. The crown was the most highly deteriorated portion of the anchor. A 200 x 300 x 25mm section of the crown had delaminated and was missing. The area was cleaned to good metal and sealed. The anchor's shank was twisted about five degrees. The area where the stock would have been had two studs projecting out 50mm from the shank; these are presumed to be mounting points for a wooden stock.

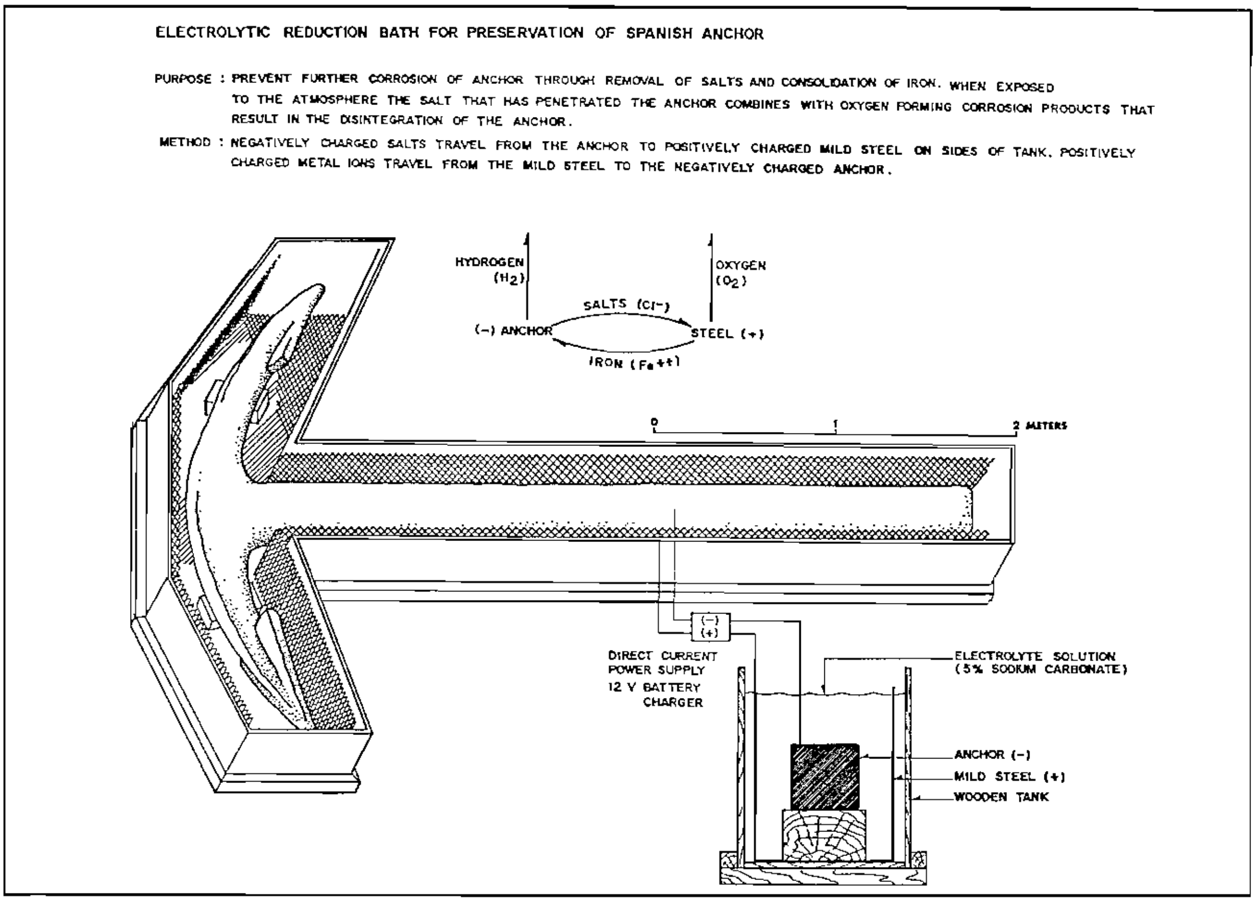


Figure 10

B. CERAMIC SHARDS

Recovered ceramic artifacts of earthenware, stoneware and Ming porcelain were cleaned and desalinated by PSR's conservation staff onboard the *Tengar*. The earthenware shards were washed and cleaned with tap water and a soft-bristled brush to remove any loose encrustation from the surface; a scalpel blade was used to remove hard encrustations. Acid solution was not applied since it might damage the specimens by making them porous and ruin them for analytical studies.

Stoneware shards were likewise washed and cleaned with water and brush. Soaking shards in a five percent solution of hydrochloric acid, plus the use of a scalpel, removed remaining hard encrustations. The porcelain fragments were also soaked in a five percent solution of oxalic acid in order to remove iron and organic stains.

All ceramic shards were desalinated by placing them in a plastic tub filled with fresh water. The water was changed regularly until free of chlorides, as confirmed by silver nitrate tests. Distilled water was used for final desalination; the process was considered complete once readings on the conductivity meter stabilized at approximately 220 microsiemens.

A variety of tests were performed on the ceramic shards; the results showed all samples had similar properties. Colors were determined by comparing the specimens to the standard Munsell soil color chart. Porosity was determined by the soaking and weighing method. Each sample had a porosity in the zero to five percent range, indicating that most were stoneware.

C. STORAGE JARS

In addition to shards, 156 intact storage jars were cleaned and desalinated. Each jar was encrusted with coral and algae up to 20cm thick. Many were found partially buried in sand with buried areas devoid of marine growth. Removal of the gross encrustation was accomplished with a hammer and small chisel until no more than 1-2mm of coral remained. At first, the jars were then immersed in an 3.7 percent nitric or hydrochloric acid bath. However, this procedure was soon abandoned when it was observed that the glaze from one jar began to lift, even after passing a spot test with the acid solution. The remaining encrustation was removed with a pneumatic scribe.

Conservator Myrna Clamor mechanically removing coral encrustations from storage jar with hammer and chisel

Project engineer Michael Flecker changing the fresh water during the two to three month desalination process for the storage jars

D. GLASS

Glass artifacts, mainly in the form of small beads, were desalinated, coated with Incralac, and then placed in dry storage. None were suffering from "glass disease," a condition normally indicated by an iridescent hue and flaking.

E. ORGANIC MATERIAL

Several types of organic matter were recovered, including eleven storage jar lids made of teak and a short length of rope apparently used to secure them. The rope was tentatively identified as black cordage, a strong, dense fiber from the leaf of the cauong (Arenga saccharifera) tree. Complete conservation of water-logged organic materials is an extensive and delicate process requiring specialized equipment and rigidly controlled conditions. Therefore, on-site conservation of wood, rope, and other organics was limited to storage in a five percent panacide solution to prevent fungus disease. This process has been shown to prevent further deterioration until final conservation can be undertaken. The storage jar lids were later conserved, using an acetone-rosin technique whereby the lids were thoroughly dewatered in three consecutive acetone baths, then soaked in a 40 percent rosin in acetone solution for six weeks. The lids were slowly dried over a week, then stored in polyethylene bags. Slight shrinkage was observed for three of the lids but the others responded well to this treatment. Calcified worm burrows were not removed as this would have reduced the structural integrity of the wood.

F. RESIN

One of the storage jars was recovered with its contents intact. This was a resin, identified by Dr. Rosemary Gianno, of the Smithsonian Institution, as deriving from the genus Styrax (see Appendix C). It is an important incense resin in Malasia and Indonesia, having a history of long distance trade reaching back into antiquity.

Archaeological illustrations of organic materials