Appendix

Previously unpublished Canadian Geological Survey report:

CRUISE REPORT PARIZEAU 91-062

Prepared by D.J.W. Piper

(scanned and reformatted to fit on fewer pages)

CRUISE REPORT PARIZEAU 91-062

Dates: 25 January 1992 - 4 February 1992, Sidney to San Diego

Master: Captain F. Berchem

Senior Scientist: D.J.W. Piper, A.G.C.

Responsible agency: Atlantic Geoscience Centre

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INTRODUCTION

Objectives

The original objective of this cruise was to define, using various seismic reflection profiling systems, the growth pattern of Navy Fan (offshore from San Diego in the California Continental Borderland) over the past few hundred thousand years. Specifically, the goals were to better understand the processes that lead to the formation of sandy submarine fans and the role of sea level changes in their formation. This seismic work was also intended as a site survey for possible ODP shallow drilling. Because permission to work in Mexican waters was refused (25 Jan 1992), the same objectives were addressed on the Hueneme fan complex in Santa Monica Basin, California. The transit of CSS Parizeau provided a unique opportunity to study such modern sandy submarine fan deposits in water depths shallow enough for Huntec profiling.

Cruise summary

About 850 line km of high quality Huntec DTS and sleeve gun reflection profiles were obtained of Hueneme, Mugu and Dume submarine fans, Santa Monica Basin, off southern California. The data show for the first time the detailed distribution of sand bodies on a modern sandy submarine fan.

Scientific highlights

1. The detailed 3-dimensional geometry of sand and mud deposits in a modern submarine fan has been determined from upper fan valley to basin floor, with a thickness resolution of about 1 m. This is the first time that stratigraphic resolution comparable with outcrops on land is available from a modern sandy submarine fan.

2. Variations in sediment type, supplied by various pathways into Santa Monica Basin and the adjacent basin slopes, are inferred to be related to sea-level change. If true, then the alternation of sandy and muddy deposition may provide a chronostratigraphy, for the fan sequences, allowing assessment of models relating deep-water sand deposition to sea level changes.

3. The survey provides high-quality data for an ODP proposal to examine sandy turbidite facies on a modern fan.

4. The improved understanding of sand-body geometry is directly relevant to hydrocarbon exploration and exploitation in deep-water sands.

Scientific staff

David J.W. Piper	AGC
William R. Normark	US Geological Survey, Menlo Park
Richard N. Hiscott	Memorial University of Newfoundland
Martin Guerrero	Universidad Autonoma de Guerrero, Mexico
Jess Nielsen	Seismic tech, AGC
Austin Boyce	Electronics tech, ACC
Roy Sparkes	Navigation and data tech, AGC
Graham Standen	Huntec tech, Axys Environmental

Summary of problems and recommendations

No significant problems were encountered; the Master, officers and crew supported the program in every possible way despite their workload related to running a new ship. A variety of minor suggestions concerning the ship have been passed on orally to the Chief Officer.

As for issues of concern to ACC, the SE880 digital recorder provided most of our problems: details are given below. In particular, note the recommendation on STOP function and the problems of setting the recording window. One of two seismic LSR recorders was unsatisfactory, and was replaced with the 3.5 kHz LSR. There was one 2-hour failure of the Huntec console unit; and the float for the sleeve gun was lost early in the survey.

LOG OF OPERATIONS

DETAILED NARRATIVE

January 25th, JD025.

Departed Patricia Bay at about 1530 PST after carrying out tests on the ship in Saanich Inlet for most of the day.
January 26th–27th, experienced strong headwinds and heavy seas.
January 28th–30th, experienced good weather and made good time.

JD030, January 29–30th

Contacted Coast Guard for further information on Notship re Navy experiments requiring 80 mi radius on seismic. Both San Diego Coast Guard and us unable to contact the ships involved or gain further information. Decided that our system at 40 mi was weaker than a regular seismic system at 80 mi and would go ahead with work unless we were contacted.

Light winds, sea state 2.

Arrived at start of survey area off Anacapa Island at 1430 PST, 2230 Z.
1 mile before point A, slow to deploy Huntec, sleeve gun, SE eel and NSRF eel.
Fired sleeve gun at 1200 psi, to reduce seismic energy.

A 34 02. 0 N 119 16. 0 W
run Line 001 to point B at 4.5 knots
B 33 50.5 N 119 17.5 W

JD031, January 30–31st

Almost calm most of day, sea state 1–2.

make turn to port through point B
to C 33 46.4 N 118 47.0 W
continue line 003 to D, at right angles to shipping lanes
D 33 51.3 N 118 45.1 W
continue line 004 to E
E 33 52.8 N 118 36.5 W on edge of Santa Monica Shelf
0.5 miles before E make turn to starboard to come onto line 005 from E to F
F 33 35.4 N 118 43.1 W in SW corner of Santa Monica Basin
0.5 miles before F make turn to starboard to come onto line 006 from F to G
G 33 52.75 N 119 07.1 W
at point G about 1040 PST 1840 Z
turn slowly to come onto line 007 from G to H across Hueneme mid–fan
H 33 54.65 N 119 21.0 W
turn to come onto line 008 from H to I
I 33 52.78 N 119 21.0 W
turn to come onto line 009 from I to J
J 33 49.65 N 118 59.0 W
0.5 miles before J' make turn to starboard to come onto line 010 from J to K
K 33 46.15 N 119 00.0 W

JD032, January 31st - February 1st

Light winds, sea state 2-3.

0.5 miles before K make turn to starboard to come onto line 011 from K to L
L 33 48.1 N 119 14.0 W
pass through L and make turn to starboard to come onto line 012 from L to M
M 133 58.0 N 119 11.35 W
at M make turn to starboard to come back onto line 013 from N to O

N 33 57.63 N 119 09.1 W
O 33 48.65 N 119 11.45 W
0.5 lles before O make turn to port to come onto line 014 from O to P
P 33 45.9 N 118 52.0 W
at P make turn to port to come back onto line 015 from Q to R
Q 33 47.8 N 118 51.5 W
R 33 51.7 N 119 20.0 W
pass through R and turn to starboard to come onto line 016 from R to S
S 33 59.15 N 119 18.0 W
0.5 miles before S make turn to starboard to come onto line 017 from S to T
T 33 58.5 N 119 13.65 W
run line 018 from T to U
U 33 52.8 N 119 15.15 W
then turn to stbd and come onto line 019 from U to V
V 33 54.0 N 119 23.45 W
at V make a slow turn to stbd and come onto line 020 from V to W
W 33 56.1 N 119 17.2 W
at W, turn onto line 021 from W to X
X 33 53.9 N 119 02.0 W

JD033, February 1st-2nd

Light winds, sea state 2-3.

at X, turn onto line 022 from X to Y
Y 33 51.0 N 119 02.7 W

Brought up Huntec fish on deck at X to correct fins. When put back in water and switched on, part of console rack blew up. Continued lines with sleeve gun and 3.5 kHz. Huntec down for two hours, restarted near end of line 023. Problem was burnt out power supply.

at Y, turn onto line 023 from Y to Z
Z 33 52.6 N 119 14.0 W
Huntec now fully operational again.

turn onto line 024 from Z to AA
AA 33 56.4 N 119 12.9 W
turn onto line 025 from AA to BB
BB 33 55.3 N 119 05.1 W
turn onto line 026 from BB to CC
CC 33 44.0 N 119 08.3 W
at CC make very slow turn to port to come to point DD
run line 027 from DD to EE
DD 33 44.0 N 119 06.65 W
EE 33 53.15 N 119 04.0 W
turn slowly onto line 028 from EE to FF
FF 33 53.7 N 119 07.8 W
turn slowly onto line 029 from FF to GG
GG 33 46.2 N 119 10.0 W
turn a little short of GG onto line 030 from GG to HH
HH 33 57.25 N 119 15.5 W
then turn to stbd to run line 31 from HH to II
II 33 56.55 N 119 10.5 W
then turn to stbd to run line 32 from II to JJ
JJ 33 47.7 N 119 13.1 W

after JJ, make very slow port turn to come to point KK and run line 33 from KK to LL

KK	33 47.1 N	119 10.95 W
LL	33 54.0 N	119 09.1 W

then turn slowly to port just before point LL to run line 34 from LL to MM

MM	33 56.0 N	119 23.2 W

turn to port at about 1.5 mi before point MM (on northwestern basin margin), and run line 35 from MM to NN

NN	33 58.5 N	119 18.9 W

JD034, February 2nd-3rd

Light winds, sea state 2-3, except in morning, when sea state 3-4.

turn to run line 36 from NN to OO

OO	33 56.7 N	119 08.0 W

turn slowly to port just before OO to run line 37 (across shipping lane) to PP (upper Mugu Fan)

PP	34 00.5 N	119 06.0 W

turn to stbd and run line 38 to QQ

QQ	33 59.8 N	119 04.25 W

turn to stbd and run line 39 (across shipping lane) to RR

RR	33 52.1 N	119 07.2 W

after passing through RR, make slow turn to port to run line 40 from SS to TT (across shipping lane)

SS	33 52.4 N	119 05.0 W
TT	33 58.9 N	119 02.3 W

turn to stbd to run line 41 from UU to VV (across shipping lane)

UU	33 58.6 N	119 01.5 W
VV	33 50.7 N	119 03.4 W

turn to stbd to run line 42 to WW

WW	33 52.4 N	119 15.7 W

turn to stbd to run line 43 from XX to RR

XX	33 53.15 N	119 15.6 W
RR	33 52.1 N	119 07.2 W

turn to stbd to run line 44 to YY

YY	33 50.4 N	119 07.65 W

turn to stbd to run line 45 to ZZ

ZZ	33 51.85 N	119 17.65 W

turn just before ZZ to stbd to run line 46 to AI

AI	33 55.3 N	119 09.05 W

at about longitude 119 11.0 W, lab requested end of line. Then turn slowly to port to begin line 47 from BI' to CI'

BI'	33 56.0 N	119 12.0 W
CI	33 56.85 N	119 16.0 W

turn to stbd and run line 48 from CI' to DI

DI	33 59.7 N	119 15.5 W

turn to stbd and run line 49 from DI to EI'

EI'	33 56.0 N	119 07.1 W

JD035, February 3rd-4th

Light winds, sea state 2

turn to port and run line 50 from EI' to FI (across shipping lane)

FI	34 00.15 N	119 05.05 W

some deviation to avoid traffic

turn to stbd and come to GI, run line 51 from GI to HI (across shipping lane)

GI	33 59.2 N	119 03.5 W
HI	33 55.0 N	119 05.25 W

turn to port and run line 52 from HI to JI

JI	33 53.05 N	119 01.3 W

turn to port and run line 53 from JI to KI (across shipping lane)

KI	33 56.65 N	118 56.5 W

turn to stbd and run line 54 from KI to LI

LI	33 54.0 N	118 47.9 W

break line 54 at longitude 118 52 W
Run line 55 to MI (across shipping lane)

MI	33 47.7 N	118 52.0 W

turn to stbd and run line 56 from MI to NI

NI	33 50.35 N	118 55.65 W

turn to stbd and run line 57 from NI to OI (across shipping lane)

OI	33 54.7 N	118 51.25 W

shortly before OI, make slow turn to stbd and run line 58 to PI

PI	33 53.0 N	118 48.0 W

Brought in Huntec at OI and seismic about 1 mi towards PI. Clear at 2145 PST.

EQUIPMENT USED

Navigation

Navigation was provided by two Northstar 800 Loran-C receivers each interfaced with a Northstar 8000X GPS receiver. One receiver set was located on the ship's bridge for navigating the survey lines, and the other placed in the ship's General Purpose Lab. for logging and plotting.

The Northstar 800-8000X GPS was configured for the U.S. West Coast chain (9940) which then builds an almanac of ephemeral data from the GPS satellites. Once navigating, the receiver automatically selects either Loran-C or GPS for ship positioning depending on which system provides the better signals at the given time. The advantage of this coupled system provided a better control for the survey area since data gathered from the GPS system automatically calibrates the accuracy of the coordinates derived from the Loran-C receiver.

Attempts to log the navigation data to disk after the storm of January 26th resulted in a piercing alarm every 25 seconds. Data were therefore printed out, and fixes every five minutes (plus bathymetry) were manually entered to disk.

GPS fixes were available except from 1800Z/032 to 0100/033, 1930/033 to 0200/034 and 1500/034 to 2350/034, when Loran-C was used as the basis of navigation. Unfortunately, the recorder did not set off an alarm or log when it switched from GPS to Loran.

Seismic reflection profiling

Seismic lines were run at about 5 knots, except for the first two lines run at 4.5 knots. The standard AGC seismic equipment used consisted of:

- Seismic Engineering hydrophone 100 ft.
- NSRF Mark 5a hydrophone 18 ft.
- Texas Instruments sleeve gun 40 cu/in.
- Rix compressor K88 run at 1200-1400 psi
- Hydrophone amplifiers (62 db fixed and variable)
- Time varying gain amplifiers
- Krohn-hite filters
- two LSR 1811 graphic recorders
- CBC-AGC clock and firing box
- HP 3968A 8-channel tape recorder.

The following channels were used on the tape recorder:

1 NSRF signal
2 Seismic trigger
3 25 foot SE streamer
4 100 foot SE streamer
5 Huntec Internal signal
6 Huntec 6.4 Khz signal
7 Huntec trigger
8 Huntec External signal

The sleeve gun data on the 100 ft section of the SE eel were displayed at 2.5 sec. sweep with a firing rate of 3 seconds, and a routine delay of 0.4 secs was applied except in shallow water. The 25 ft section was taped but not displayed. The NSRF eel data was displayed at 1 sec sweep with typically an 0.7 sec delay.

Huntec DTS

The following equipment was used:

A.G.C. # 2 540 Joule system
Internal Hydrophone - LC 10.
External Hydrophone - Benthos mesh 10 element, 15 feet long
Signals displayed on E.P.C. 4100
All signals are via a Krohnhite filter.
External hydrophone filter settings: 500 hz - 6000 hz
Internal/p hydrophone filter settings: 2000 kz - 4500 kz.
Fire rate 750 ms
Displayed at 250 ms

Few problems were experienced with the equipment. The system console had the one failure, which was rectified, with the loss of about 2 hours of data. There were no further problems with this unit. No problems were experienced with the power control unit and filter. Neither were there problems with the 2nd Adaptive signal processor, however the power supply module from the main system console frame was replaced due to the resistor R4 failing. This resistor is not carried in the spares and was subsquently replaced by 10x100 ohm resistors in parallel. This will have to be replaced.

Both EPC 4100's worked well with no problems, but the gain and threshold on machine serial # 161 has to be rectified. The grey level is far too dark with the threshold adjustment turned fully anticlockwise. This makes the setting up of the recorder difficult, and detracts from the data presentation.

There were no problems with the winch and power pack. Apart from adjusting the tail fins, the towed body remained in the water for the complete survey. Some suggestion of a leak was detected when the fish was at a depth of about 150 m on a turn.

The Huntec fish layback was typically 2.5 minutes in the earlier part of the cruise when it was towed deeper, and 1. 5 minutes in the later part of the cruise.

SE881 Digital Seismic Data Logger

Two SE881 digital loggers were used. System AGC #1 was used to log the 100 ft SE and NSRF streamers with sleeve gun seismic. System AGC #2 was used for the internal and external Huntec DTS hydrophones.

In order to use the recommended digital sampling rate and a sufficiently large window to include all useful data, it was only possible to digitise two seismic channels (raw NSRF + 40 db on ch. 1; raw

SE 100 ft + 62 db on ch. 2) rather than the three originally planned. The SE 25 ft was therefore only recorded in analogue format (on HP3968A, ch. 3).

A variety of problems were experienced with the systems. System AGC #1 occasionally locked up on the control screen. This could be bypassed by switching the control screen off and on again, typing enter, shift-?, and then 0. Possibly "kybd-lockout-enable" should be defaulted off.

System AGC #2 commonly (15% of the time) would, after typing 1 START on the main menu prompt for source and writing to Exabyte, then drive the tape for a long time, and again prompt 1 START. This procedure appeared to reduce the number of identified files on the tape by one every time it occurred, suggesting that overwriting occurred. It seemed to take place most frequently (?exclusively) after the first file had been read onto the tape.

Signal levels from the Huntec DTS system were judged to be too low. The external hydrophone signal was amplified 20 db with a Krohn-hite filter; no amplifier was available for the internal hydrophone signal (± 1.0 v p-p of fire pulse, bottom much smaller).

Commonly (60% of the time) the system would not lock on to the correct window for recording data, presumably because it was not locking on to the trigger successfully. Best results were achieved by entering the (identical) desired delay and window twice in rapid succession. If that failed, reducing the window size until lock on was achieved, and then increasing it again, sometimes worked.

We were always concerned about accidentally stopping the recording by mis-keying 1 in the main menu. For this reason, the main menu was never kept displayed on the screen. STOP should be a two key operation. Comment or text marker entry was often not accepted, particularly on the SE880 #2. It would be useful to be able to query the SE880 as to which file number it is currently writing to.

Sounders

A Raytheon PTR 12 kHz sounder, displayed on an LSR recorder, was used routinely on a 1 sec. sweep for logging bathymetry. The ORE 3.5 kHz sounder, with hull-mounted transducers, was used on those lines when the Huntec DTS system was not working.

PRELIMINARY SCIENTIFIC RESULTS

INTRODUCTION AND PREVIOUS WORK

A series of submarine canyons lead from the California coast to Santa Monica Basin and have built a series of small sandy submarine fans. From northwest to southeast these are Hueneme, Mugu, Dume, Santa Monica, and Redondo fans. The previous detailed study of the area, by Nardin (1981, 1983), concluded that, "in general, large-scale fan growth fits Normark's model in which the suprafan is the primary locus of coarse sediment deposition". Nardin was also able to demonstrate an impact of changing sea level on the fans, with a restriction in the area of fan sedimentation between 18 ka and 10 ka during the isotopic stage 2 to 1 rise in sea level, when sediment was trapped on the narrow shelves. Santa Monica Basin therefore was chosen as the study area to address the objectives originally intended for Navy Fan because of the similarity of the sandy fan systems and the potential for studying the effects of sea level change. This choice had the advantage of being in half the water depth of Navy Fan, resulting in higher quality Huntec DTS profiles.

Much of Nardin's work included studies of the shelves and basin slopes adjacent to Santa Monica Basin, and a detailed study of San Pedro Basin. He had a grid of 3.5 kHz profiles at 5-10 km spacing on the fan and a few 10 cu inch airgun profiles spaced at about 15 km, in addition to some deeper penetration seismic data. Location of the seismic data is shown by Teng and Gorsline (1989, their figs. 2-4). Subsequently, GLORIA data was obtained from Santa Monica Basin (EEZ-Scan 84 Scientific Staff, 1986), that has recently been interpreted by Edwards et al. (in prep.) in conjunction with available samples and high-resolution profiles. Large numbers of box cores and fewer short piston cores are available from the basin (e.g. Reynolds, 1987; Edwards et al., in prep).

The basins of the California Borderland have subsided in a predominantly strike-slip tectonic regime. Related folding has resulted in a growing anticline along the southeastern margin of Santa Monica Basin, across lower Santa Monica canyon. Otherwise, the basin appears to have been a relatively stable depocentre since the Pliocene (Teng and Gorsline, 1989).

Nardin (1981, 1983) applied sequence analysis to his seismic reflection profiles, recognising two mid to late Quaternary units (C and D) inferred to have been deposited in the past 0.5 Ma. He noted that Dume fan was active in sequence C, but has been onlapped by later basin plain sediments (90 m thick, sequence D). He also recognised an "8-m reflector" at a sub-bottom depth of 8 m in southeastern Santa Monica Basin that piston cores indicate corresponds approximately to the base of the Holocene at 10 ka. He was unable to trace this reflector onto Hueneme and Mugu fans.

Sedimentologic setting

The narrow continental shelf off southern California receives sediment from small ephemeral rivers. Sand is transported southeastward in longshore drift until intercepted by a submarine canyon at the downdrift end of a littoral cell. Mud on the shelf is periodically resuspended by storm waves and advected southeastward in the prevailing current and seaward into the basins. Hueneme canyon is the first canyon at the eastern end of the long Santa Barbara littoral cell; the canyons to the southeast are fed by much shorter lengths of littoral cell. Contemporary sedimentation rates and river sources are reviewed by Schwalbach and Gorsline (1985).

Sand is transported into the basins by turbidity currents flowing down the shelf-cutting canyons. Some mud is also transported by turbidity currents; some by episodic high-concentration storm advection; and some by "background" hemipelagic processes. Slope failure occurs on steep basin margins. At present, little sediment, coarse or fine, is deposited on the continental shelf, which is a zone of sediment bypassing. Nardin (1983) identified significant shelf trapping of sediment during the earliest stages of marine transgression, resulting in decreased sediment supply to the basins.

Although sea level changes do not change the basic processes of sediment transfer from the coastal zone to the basins, rapid sea level rise may lead to filling of canyons that receive only a limited sediment supply (such as the Holocene Santa Monica canyon: Nardin et al., 1981). At sea level lowstands, there is no continental shelf, and smaller canyons may become re-activated. River-derived mud is more likely to be deposited directly in the basin opposite its mouth, rather than being advected along the shelf. Whether sediment yield is greater during glacial stages is a debated point.

Bathymetry

Santa Monica Basin reaches a maximum depth of 938 m in the ponded southern part, rising gently to the northwest to Hueneme Fan, which forms a pronounced bathymetric lobe at 750 - 850 m. Hueneme fan valley is a visible bathymetric feature at about 700 m water depth.

Of the canyons on the margin of Santa Monica Basin, Hueneme, Mugu, Dume and Redondo are all incised into the shelf and head near the present coastline; Santa Monica canyon has not eroded back across the shelf. Redondo canyon at present leads to San Pedro basin, not to Santa Monica Basin. There is a series of slope gullies between Hueneme and Mugu canyons.

Bathymetry was digitised at 5 min intervals from the 12 kHz sounder. The dense, well navigated, data grid should permit compilation of a bathymetric map of Hueneme fan at a contour interval of 10 m.

RESULTS: HUNTEC DTS RECORDS

Data quality and facies interpretation:

Excellent data was obtained with the internal hydrophone; the “pseudo-internal” data (external hydrophone filtered 2kHz - 4 kHz) gave similar resolution but better penetration. Penetration was at least 15 ms and commonly as much as 80 ms in muddy areas. The regular external hydrophone record (filtered 500Hz - 6 kHz) shows deeper reflectors, commonly >50 ms in muddy sections, that can be correlated with the NSRF sleeve gun record. The directions in which seismic lines could be run was partly constrained by the need to cross the shipping lanes in eastern Santa Monica basin orthogonally.

Preliminary facies interpretations are based on published descriptions of cores (Nardin, 1983; Reynolds, 1987; Edwards et al., in prep.) and by comparison with deep-water sediments on the Var submarine fan (Piper and Savoye, in prep.). Reflection amplitude is used to distinguish "mud" from "silty mud with thin sands" in relatively transparent areas of continuous reflectors. Higher amplitude reflections with less continuity are assumed to be sandier. Zones of incoherent reflections may either be sand packets, or slumps and debris flows. Final interpretation of this acoustic facies will depend on a more thorough assessment of the penetration of acoustic energy and the geometry of such deposits; shipboard interpretation suggests that many are sand bodies, but that some slumps may be present.

Stratigraphy:

There is enough continuity of reflectors and a detailed grid of survey lines for a consistent seismostratigraphy to be developed for the entire region. There was insufficient opportunity on board ship to make such correlations systematically.

Hueneme fan appears to have been active in the Holocene, with near surface sand deposits. These pass laterally into draped silty muds downslope from the slope gullies between Hueneme and Mugu canyons, that in turn overlie a gullied surface over more extensive sand, presumably stage 2 lowstand deposits (2300Z/032 - 0030Z/033). However, these same draped muds appear to onlap Hueneme fan valley levees, suggesting that the upper fan valley is a bypass feature as a result of Holocene headward erosion of the canyon (cf. La Jolla Fan: Piper, 1970).

At the extreme northwestern margin of the basin, there is a relatively smooth transition from marginal fan deposits to hemipelagic drape on Santa Cruz - Catalina Ridge (2150Z/032). The reflection intensity in Holocene hemipelagic sediments decreases upslope, suggesting decreasing turbidite influence. The hemipelagic sediments show an alternation of more and less reflective packets that may provide a basic (sea-level related) stratigraphy; the same packets are recognised in the NSRF sleeve gun records.

Hueneme fan:

On Hueneme fan, the following general changes are seen down fan:

1. The main channel on the upper fan has muddy levees. The channel appears to contain several sand packets on its floor. The innermost levees have grown over older channel-floor deposits seen on the sleeve gun profiles and show widespread surface erosion (?Holocene), over a thick accretionary section (late stage 2?), overlying another erosion surface (2250-2300Z/032).

2. A zone of rather hummocky seabed, with little penetration. This is interpeted as sands, perhaps with common flute-like scours.

3. A zone of greater penetration with lenticular sand sheets and interbedded muds. Some sheets show compensation cycles (Mutti and Sonnino, 1981). The sands show gradual downfan thinning. The bases of sand sheets are erosional in more proximal areas and the tops of sheets are locally cut by small channels or scours. Sand is most common in front of the main channel. This zone and zone 2 are well illustrated between 1500Z and 1650Z/032.

4. There is a gradual decrease in sand towards the basin floor, where deposits appear predominantly muddy and form wedges that thicken basinward. At 0310-0315Z/035, on the basin floor, is a near-surface feature interpreted as in situ liquefaction, or possibly a muddy debris flow.

The western levee of Hueneme fan has prominent muddy sediment waves. Lines were run in a variety of directions to determine their orientation.

At the base of the SW basin margin slope on lower Hueneme fan, "sheet" sands thin out between an over- and underlying mud drape. There is a pronounced small leveed channel at the actual base of slope (e.g. 0400Z/032); this channel dies out distally (e.g. 1347Z/033).

Mugu fan

Mugu fan has a leveed upper fan valley, with mud waves on the western levee and the eastern levee confined against the basin margin. The western levee dies out rapidly, the channel broadens and three small talweg channels are incised 20 m into a broad sandy suprafan. These die out as prominent features downfan, where the sandy suprafan has an indeterminate irregular surface. In this area, there appears to be an interfingering of Mugu and Hueneme fan deposits. Mugu fan appears to be a steeper feature than Hueneme fan, and shows much more rapid facies changes.

Dume fan

Dume fan was examined in only a reconnaisance manner. It is steeper than Mugu fan. Beneath a 10-15 ms thick surface layer of stratified muds is a steep "suprafan" sandy surface, cut by a surface channel or channels. In places, this surface resembles a gravel wave surface in its acoustic character. This sandy surface gives way to mud waves on the upper part of the fan (0155-0203Z/035).

RESULTS: SLEEVE GUN RECORDS

The 100 ft SE eel provided good data typically to depths of 1.2 sec; the NSRF eel to about 0.4 sec. No systematic study has yet been made of features visible in the seismic profiles.

In the deeper parts of Santa Monica Basin, reflections are generally flat lying, but towards basin margins repeated onlap relationships are visible. One rather transparent unit appears to be a debris flow onto which turbidites onlap (e.g. 1410-1530Z/034 on NSRF).

Seismic data show that Dume fan consists of a stack of steep sandy suprafan lobes, the youngest of which appears to be onlapped by at least 40 ms and possibly 200 ms thicknesses of basin sediment (0200-0230Z/035).

The most spectacular seismic data, however, is on the upper part of Hueneme fan and the gully systems immediately to the east. These show a periodic westward migration of channels and levees between Mugu and Hueneme, with the western levee of an old system forming the eastern levee of a new system (0000-0200Z/034). More sand rich and more mud rich intervals are inferred from the seismic profiles, and beneath Hueneme fan valley at least three stacked levee-channel units can be recognised. The youngest fan valley has developed low levees inside the older higher levees and the proximal sandy suprafan actually appears to sit in the distal upper fan valley. These last two points suggest that the most recent, sandy deposits form a smaller-scale system that is superimposed on the larger mud-dominated leveed channels. Such changes in scale and dominant grain size may be related to sea level variations.

Thus the seismic data record a complex history of changing sediment sources, variation in relative abundance of sand, and channel size. If the sedimentological consequences of stage 3 to 2 to 1 sea-level changes can be inferred from datable parts of the stratigraphy sampled in extant cores, it may be possible to use the chronology of older sea-level changes to infer ages for deeper stratigraphic horizons.

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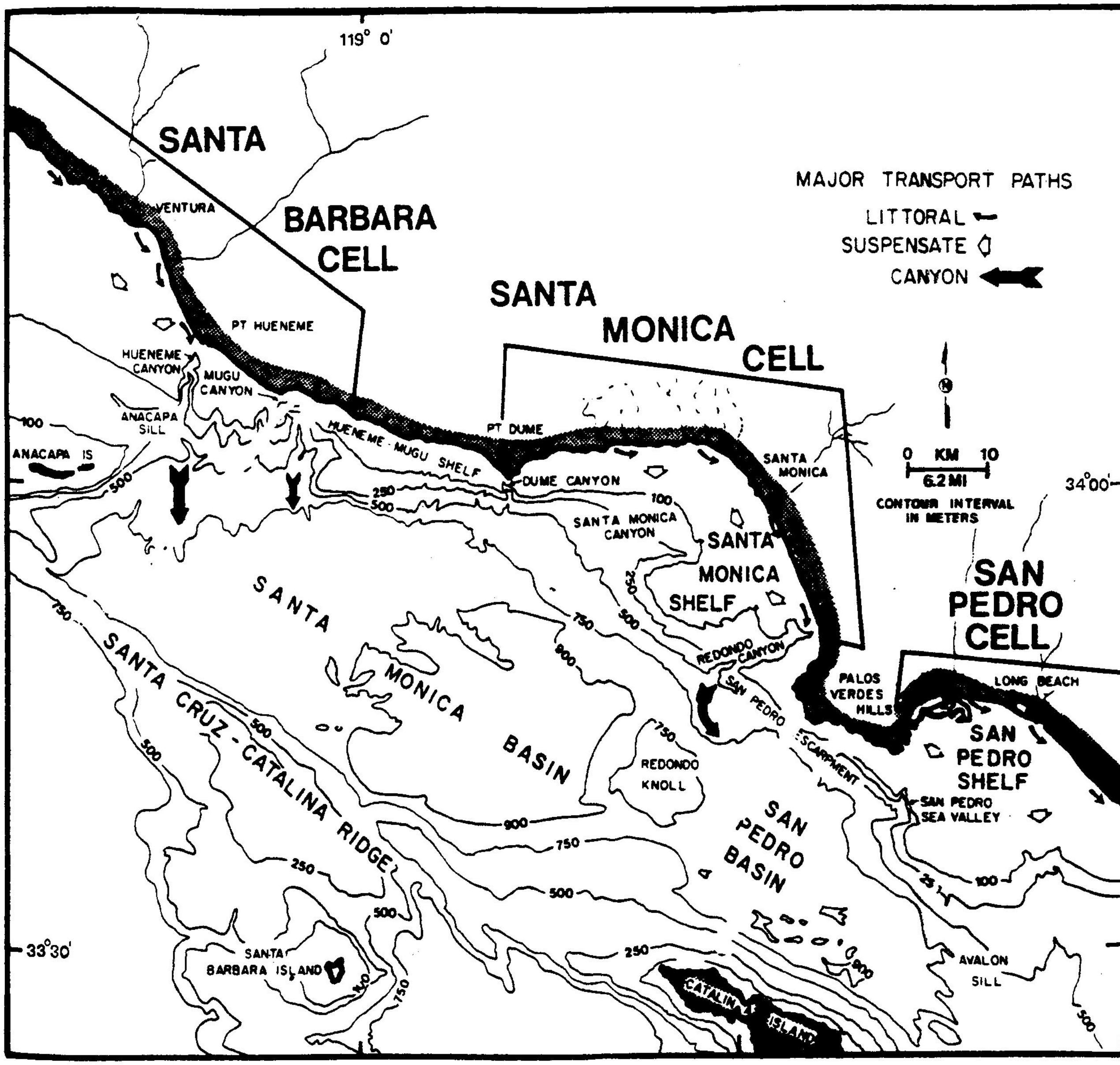

Fig. 1. Bathymetric map of Santa Monica Basin showing principal sediment transport paths.
(after Nardin, 1983). "Cells" are littoral drift cells that terminate down-drift in a submarine canyon.

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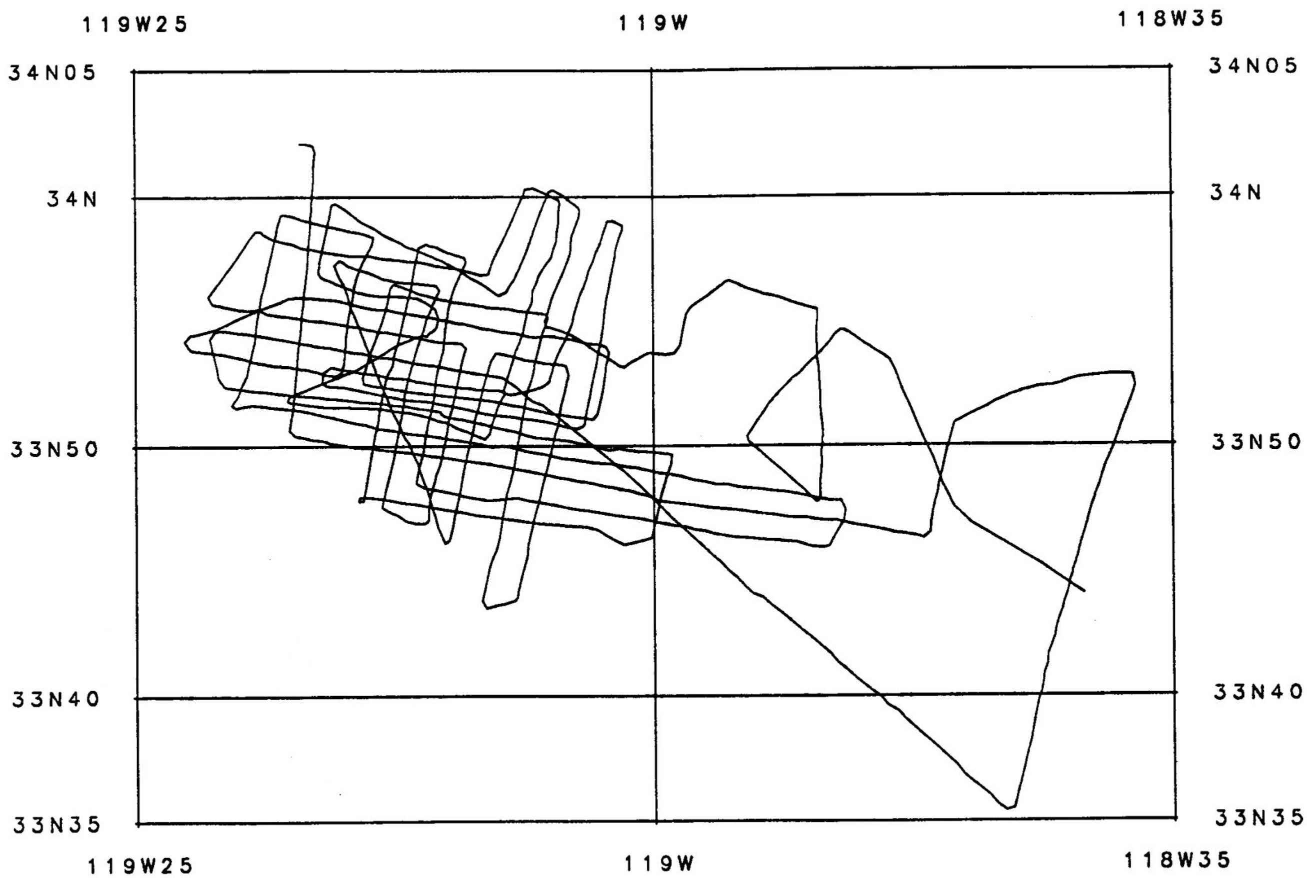

Scale 500000:1
Projection Mercator Ref Lat=32N

LINE NUMBER START/STOP TIMES

Start Day/Time	End Day/Time	Line No.
030/2220	031/0115	Line 1
031/0120	031/0700	Line 2
031/0707	031/0728	Line 3
031/0801	031/0933	Line 4
031/0941	031/1328	Line 5
031/1330	031/1833	Line 6
031/1834	031/2048	Line 7
031/2056	031/2115	Line 8
031/2121	032/0054	Line 9
032/0100	032/0135	Line 10
032/0140	032/0358	Line 11
032/0408	032/0604	Line 12
032/0633	032/0814	Line 13
032/0820	032/1145	Line 14
032/1220	032/1652	Line 15
032/1659	032/1820	Line 16
032/1821	032/1908	Line 17
032/0913	032/2025	Line 18
032/2030	032/2139	Line 19
032/2149	032/2240	Line 20
032/2250	033/0135	Line 21
033/0139	033/0216	Line 22
033/0227	033/0415	Line 23
033/0420	033/0508	Line 24
033/0511	033/0646	Line 25
033/0650	033/0909	Line 26
033/0932	033/1130	Line 27
033/1136	033/1209	Line 28
033/1213	033/1347	Line 29
033/1355	033/1620	Line 30
033/1624	033/1715	Line 31
033/1718	033/1907	Line 32
033/1938	033/2114	Line 33
033/2119	033/2320	Line 34
033/2335	034/0005	Line 35
034/0008	034/0205	Line 36
034/0212	034/0300	Line 37
034/0305	034/0320	Line 38
034/0324	034/0504	Line 39
034/0536	034/0707	Line 40
034/0717	034/0855	Line 41
034/0859	034/1057	Line 42
034/1110	034/1252	Line 43
034/1256	034/1321	Line 44
034/1325	034/1508	Line 45
034/1514	034/1646	Line 46
034/1714	034/1752	Line 47
034/1758	034/1829	Line 48
034/1832	034/2015	Line 49
034/2021	034/2108	Line 50
034/2130	034/2222	Line 51
034/2228	034/2312	Line 52

Start Day/Time	End Day/Time	Line No.
034/2322	035/0033	Line 53
035/0040	035/0125	Line 54
035/0128	035/0303	Line 55
035/0307	035/0347	Line 56
035/0352	035/0505	Line 57
035/0512	035/0550	Line 58

TABLES OF DATA FROM CRUISE

Huntec records

Roll Number	Start Day/Time	End Day/Time	Type
1	030/2245	031/0930	Internal (Pseudo)
2	030/2310	031/0925	External
3	031/0935	031/1115	Internal (Pseudo)
4	031/0935	031/1330	External
5	031/1120	031/1830	Internal (Pseudo)
6	031/1840	032/0150	Internal (Pseudo)
7	032/0155	032/0810	Internal (Pseudo)
8	032/0820	032/1650	Internal (Pseudo)
9	031/0331	031/2045	External
10	031/2050	032/0600	External
11	032/0630	032/1650	External
12	032/1705	033/0135	Internal (Pseudo)
13	033/0340	033/1205	Internal (Pseudo)
14	032/1705	032/2235	External
15	032/2245	033/0905	External
16	033/0910	033/1620	External
17	033/1215	033/2110	Internal (Pseudo)
18	033/1630	033/2315	External
19	033/2125	034/0335	Internal (Pseudo)
20	033/2325	034/0855	External
21	034/0340	034/1100	Internal (Pseudo)
22	034/0905	034/2020	External
23	034/1105	034/1825	Internal (Pseudo)
24	034/2025	035/0000	External
24	034/1830	035/0505	Internal (Pseudo)
25	035/0010	035/0505	External

Bathymetry

Roll Number	Start Day/Time	End Day/Time	Type
1	030/2230	031/1715	12 Khz
2	031/1745	033/2110	12 Khz
3	033/2125	035/0650	12 Khz
1	033/0210	033/0342	3.5 Khz

Airgun Seismics

Roll Number	Start Day/Time	End Day/Time	Type
1	030/2250	031/1830	NSRF
2	030/2255	032/0130	100' SE
3	031/1840	033/1345	NSRF
4	032/0145	033/1135	100' SE
5	033/1350	033/2110	NSRF
6	033/1145	035/0530	100' SE
7	033/2125	035/0530	NSRF

Analogue tapes

Tape Number	Start Day/Time	End Day/Time	Line Number
1	030/2348	031/0055	1
2	031/0056	031/0256	1, 2
3	031/0302	031/0439	2
4	031/0441	031/0616	2
5	031/0617	031/0753	3
6	031/0755	031/0931	3, 4
7	031/0933	031/1138	5
8	031/1139	031/1457	5
9	031/1320	031/1457	6
10	031/1459	031/1636	6
11	031/1637	031/1815	6
12	031/1816	031/1952	7
13	031/1952	031/2130	7, 8
14	031/2134	031/2308	9
15	031/2310	032/0050	9
16	032/0050	032/0229	10, 11
17	032/0230	032/0411	11, 12
18	032/0412	032/0552	12
19	032/0533	032/0728	12, 13
20	032/0728	032/0907	13, 14
21	032/0910	032/1047	14
22	032/1049	032/1226	14
23	032/1227	032/1404	15
24	032/1406	032/1542	15
25	032/1543	032/1721	15, 16
26	032/1721	032/1858	16, 17
27	032/1900	032/2039	17, 18
28	032/2041	032/2219	19, 20
29	032/2220	032/2357	20, 21
30	032/2358	033/0135	21
31	033/0137	033/0314	22
32	033/0314	033/0451	23, 24
33	033/0452	033/0629	24, 25
34	033/0630	033/0807	25, 26
35	033/0811	033/0948	26, 27
36	033/0950	033/1127	27
37	033/1129	033/1306	27, 28
38	033/1308	033/1445	29, 30
39	033/1447	033/1622	30
40	033/1624	033/1824	31,32

Tape Number	Start Day/Time	End Day/Time	Line Number
41	033/1825	033/2032	32,33
42	033/2034	033/2211	33,34
43	033/2214	034/0019	34,35
44	034/0020	034/0225	36,37
45	034/0226	034/0428	37, 38, 39
46	034/0429	034/0630	39, 40
47	034/0631	034/0835	40, 41
48	034/0837	034/1040	41, 42
49	034/1042	034/1246	42, 43
50	034/1247	034/1451	43, 44
51	034/1452	034/1654	45, 46
52	034/1700	034/1858	47, 48
53	034/1758	034/2102	48, 49
54	034/2103	034/2206	49, 50, 51
55	034/2208	035/0112	52, 53
56	035/0113	035/0318	54, 55, 56
57	035/0319	035/0524	57, 58

Digital Tapes

Tape Number	Start Day/Time	End Day/Time	Line Number	Type
1	031/0000	031/0120	1	Seismics
2	031/0120	031/1347	2 - 21	Seismics
3	033/0129	034/2316	22 - 53	Seismics
4	035/0039	035/0529	54 - 58	Seismics
1	031/0000	031/1840	1 - 6	DTS
2	031/1840	031/1655	6 - 15	DTS
3	032/1700	032/1717	16 - 32	DTS
4	033/1921	034/1102	33 - 43	DTS
5	034/1301	035/0505	44 - 57	DTS

Digital Tape (Exabyte) Summary Log - AGC #1

Tape Number	File Number	Start Day/Time	End Day/Time	Number of Shots	Remaining at EOF	Line	Comments
1	1						No EOF
2	1						
			031/1833	?	1440		
		031/1835					
			031/2047	2638		7	
2		031/2051	031/2117	512	1332	8	
	7	031/2123	032/0053			9	
	8	032/0056		777			
	9	032/0136	032/0359	2844			
	10	032/0400	032/0815	5183	801	12, 13	
	11	032/0823	032/1149	4112	636	14	
	12	032/1152	032/1652	6020	388	15	
	13	032/1654	032/1908	2662	297	16, 17	
	14	032/1910	032/2030	1603	230	18	

Tape Number	File Number	Start Day/Time	End Day/Time	Number of Shots	Remaining at EOF	Line	Comments
	15	032/2033	032/2139	1310		19	
	16	032/2140	032/2239	1184	130	20	
	17	032/2241	033/0113	3045	12	21	
3	1	033/0129	033/0415	3325	2106	21	
	2	033/0417	033/0510	1058	2063	22-24	
	3	033/0510	033/0646	1909	1986	25	
	4	033/0649	033/0916	2960	1867	26	
	5	033/0919	033/1132	2660	1768	27	
	6	033/1135	033/1359	2887	1652	28, 29, 30	
	7	033/1401	033/1620	2792	1542	30	
	8	033/1622	033/1715	1071	1498	31	
	9	033/1717	033/1913	2313	1409	32	
	10	033/1915	033/2115	2410	1311	33	
	11	033/2117	033/2321	2484	1215	34	
	12	033/2324	034/0008	900	1175	35	
	13	034/0010	034/0209	2377	1082	35	
	14	034/0210	034/0504	3485	945	37-39	
	15	034/0507	034/0707	2411	850	40	
	16	034/0709	034/0858	2165	763	41	
	17	034/0901	034/1059	2341	672	42	
	18	034/1101	034/1253		580	43	
	19	034/1254	034/1508	2673	476	44-45	
	20	034/1511	034/1647	1931		46	
	21	034/1649	034/1828	1971	321	47, 48	
	22	034/1828	034/2018	2159	232	49	
	23	034/2021	034/2110	996	197	50	
	24	034/2112	034/2224	1440	140	51	
	25	034/2226	034/2314	967	100	52	
	26	034/2316	035/0028	1441	39	53	
4	1	035/0039	035/0124	902	2199	54	
	2	035/0126	035/0303	1950	2126	55	
	3	035/0304	035/0347	856	2090	56	
	4	035/0347	035/0529	2011		57, 58	

Digital Tape (Exabyte) Summary Log - ACC #2

Tape Number	File Number	Start Day/Time	End Day/Time	Number of Shots	Remaining at EOF	Line	Comments
1	1						
	2		031/0707	3xxx		2	
	3	031/0710	031/0935	12807		3, 4	
	4	031/0940	031/1328	5723		5	
	5	031/1400	031/1402	FEW	600	5	
	6	031/1410	031/1833	invisible	200	6	
2	1	031/1840	031/2047			7	
	2	031/2051			2026	8	
	3	032/0106	032/0134	16978		9	
	4	032/0106	032/0134	2302	1876	10	
	5	032/0304	032/0403	4747	1581	11	

Tape Number	File Number	Start Day/Time	End Day/Time	Number of Shots	Remaining at EOF	Line	Comments
	6	032/0405				12	
		032/0606	032/0604	9602	1378	12	
		032/0604	032/0816	10400	1162	13	
		032/0820	032/1148	16625	821	14	
		032/1150	032/1345	9205	620	15	
		032/1347	032/1655	15043	306	15	
3	1	032/1700	032/1908	9918		16, 17	
	2	032/1915	032/2029	5850		18	
	3	032/2031	032/2139	5351	2013	19	
	4	032/2140	032/2239	4725	1614	20	
	6	032/2141	033/0139	14251	1611	21	
	7	033/0344	033/0415	24510	1556	23	
	8	033/0417	033/0507	4090	1471	24	
	9	033/0509	033/0646	7755	1307	25	
	10	033/0648	033/0918	12024	1048	26	
	11	033/0920	033/1133	10641	826	27	
	12	033/1137	033/1348	10498	608	28, 29	
	13	033/1350	033/1620	12036	355	30 - 31	
	14	033/1623	033/1715	4211	264	32	
	15	033/1717	033/1912	9255	72	32	
4	1	033/1921	033/2116	9208	2041	33	followed by misstart
	2	033/2125	033/2320	9314	1847	34	
	3	033/2322	034/0008	3697	1765	35	
	4	034/0010	034/0209	9455	1553	36	
	5	034/0211	034/0504	13409	1139	37 - 39	
	6	034/0506	034/0707	9724	934	40	
	7	034/0709	034/0807	8661	658	41	
	8	034/0900	034/1059	9490	283	42	
	9	034/1103	034/1254		33	43	
5	1	034/1301	034/1508	10224	2234	44 - 45	followed by misstart
	3	034/1528	034/1651	6650	2011	46	
	4	034/1652	034/1828	7715	1742	47 - 48	
	5	034/1830	034/2018	8646	1431	49	
	6	034/2020	034/2111	4073	1300	50	
	7	034/2113	034/2225	5757	1133	51	
	8	034/2227	034/2315	3851	1037	52	
	9	034/2320	035/0035	5931	911	53	
	10	035/0035	035/0124	3875	827	54	
	11	035/0125	035/0303	7866	670	55	
	12	035/0304	035/0347	3397	596	56	
	13	035/0349	035/0505	6137	462	57	