FORESR – CMI SpA

PERMESSO DI RICERCA "CASERTA"

RAPPORTO FINALE SULLA CAMPAGNA GRAVIMETRICA –MAGNETICA –MAGNETOTELLURICA E GEOCHIMICA ESEGUITA NEL DICEMBRE 1999

Elaborazioni ed interpretazioni eseguite da

AOA Geophysics
e
Granath & Associates

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1. INTRODUZIONE

Il presente rapporto è una sintesi in italiano di quello originale in inglese redatto da Arnold Orange, Robert Pawlowski e James Granath per conto della Forest-CMI sulla campagna geofisica eseguita alla fine del 1999 nel permesso Caserta..

I risultati, che di seguito sono riportati, sono stati oggetto di un articolo pubblicato nel febbraio 2000 sulla rivista di geofisica "*The Leading Edge*" dal titolo "*GIS Applied to Exploration: Caserta Block, Central Apennines, Southern Italy*".

Di entrambe gli scritti alleghiamo gli originali in inglese.

1.1 Obiettivi del programma di campagna geofisica

Dalla fine di ottobre e fino ai primi di dicembre 1999 sono stati realizzati per conto della Forest – CMI SpA dei rilievi gravimetrici, magnetici, magnetotellurici (MT) e geochimici sul permesso "Caserta", ubicato nell'Italia Meridionale (figg.1-4). Le operazioni in campagna sono state eseguite dalla Geoinvest srl di Piacenza, sotto la supervisione della AOA Goephysics di Austin (Texas) che ha poi interpretato i dati e redatto gli elaborati. I risultati geofisici e geochimici sono stati inoltre integrati con altri studi geologici nell'area al fine di determinare le potenzialità complessive in idrocarburi e suggerire le necessarie raccomandazioni per ulteriori lavori di ricerca.

I dati del sottosuolo e le positive scoperte verificatesi in aree simili a quelle del permesso "Caserta", sia per obiettivi superficiali che profondi, giustificano questo programma d'esplorazione integrata.

Poiché l'acquisizione di campagne sismiche nelle zone centrali e meridionali dell'Appennino è risultata difficoltosa, i metodi di indagine alternativi utilizzati hanno permesso alla Forest-CMI di ottenere una conoscenza preliminare dell'area: la gravimetria, tramite i contrasti di densità, ha permesso di determinare i rapporti tra carbonati e flysch e di identificare i lineamenti strutturali a grande scala; i dati magnetici hanno identificato la presenza di corpi vulcanici intrusivi in un'area che ha avuto un'intensa attività magmatica; mentre quelli magnetotellurici hanno evidenziato le unità clastiche presenti al di sotto di carbonati sovrascorsi; infine i dati geochimici sono serviti a verificare se ci sono evidenze in superficie di possibili accumuli di idrocarburi nel sottosuolo.

L'acquisizione e interpretazione integrata dei dati geofisici e geologici viene presentata con una serie di mappe e sezioni.

1.2 Panorama sul programma esplorativo

Il programma esplorativo non è stato influenzato né dagli insediamenti urbani né dalla topografia dell'area che non si presenta particolarmente accidentata. I dati gravimetrici, magnetici e geochimici sono stati registrati e raccolti su strade secondarie e tratturi, lungo una serie di profili con andamento NW-SE. I dati magnetotellurici sono stati registrati in siti selezionati sulla base delle linee sismiche precedentemente interpretate. Lo scopo era quello di determinare se un obiettivo profondo era presente al di sotto delle falde Appenniniche.

I dati in campagna sono stati acquisiti dalla Geoinvest srl di Piacenza sotto la supervisione di uno staff di geofisici della AOA Geophysics Inc.

2. PROGRAMMA GEOFISICO - GEOCHIMICO

2.1 Prospezione gravimetrica

2.1.1 Dati Acquisiti

Sono stati acquisiti dati da 320 stazioni gravimetriche, riportate su tutti gli elaborati cartografici con dei circoli blu. I dettagli delle operazioni gravimetriche sono documentati dai rapporti di Geoinvest e AOA Geophysics.

Le stazioni gravimetriche hanno avuto una spaziatura più o meno regolare di 500m lungo allineamenti concordati, per ottimizzare al meglio la copertura dell'area, e sono state ubicate sulla base della cartografia topografica ufficiale dell'IGM e perfezionate nella posizione con l'uso del GPS; un eventuale errore di +/- 10 cm nella quota altimetrica della stazione rientra nella tolleranza della metodologia utilizzata

La lettura dei dati è stata effettuata sempre dallo stesso operatore utilizzando lo strumento LaCoste & Romberg Model G Gravity Meter. I dati acquisiti sono stati correlati ai due network ufficiali per la gravità assoluta usati in Italia (International Gravity Standardization Net, IGSN-1971 e Rete Gravimetrica Fondamentale Italiana, RGFI-1955), tramite l'uso di tre stazioni gravimetriche locali precedentemente stabilite nell'area delle operazioni.

Insieme ai nuovi dati acquisiti, sono stati utilizzati anche 508 valori da stazioni per la misura della gravità assoluta ripresi dalla NIMA (US Governemnt's National Imagery and Mapping Agency), al fine di fornire, oltre all'andamento regionale del campo di gravità, un importante veicolo per l'interpretazione delle aree limitrofe al permesso.

L'ubicazione dei siti delle stazioni NIMA è indicata con un cerchio di colore rosso in tutte le mappe elaborate

2.1.2 Procedure di elaborazione

Procedure di riduzione della gravità (standard o coerenti) sono state applicate sia ai dati acquisiti dal programma esplorativo, sia a quelli della NIMA; queste includono:

a) correzione teorica (formula NIMA,1998), che include una correzione per l'atmosfera
b) correzione standard in aria-libera (0.3086 mGal/m)
c) correzione di Bouguer (riduzione in densità di 2.63 g/cc)
d) correzione a terra (carta Hammer zone 1981 – riduzione in densità 2.63 g/cc)

L'applicazione delle procedure di cui sopra porta ai valori finali dell'anomalia in aria-libera (fig.5) e di Bouguer (fig.6) che concordano con quelli registrati dalla NIMA.

Un modello digitale del terreno altamente dettagliato è stato costruito per calcolare le correzioni di gravità per i terreni tramite l'utilizzo di tre differenti dati digitali di terreno:

a) entro i 60m dalla stazione: dati ottenuti da laser telemetro
b) tra i 60 e i 10.000m dalla stazione: dati ottenuti da IGM 20-meter DEM
c) oltre i 10.000m dalla stazione: dati ottenuti da GTOPO30 1-minute DEM

Il dato verticale di riferimento scelto per tutte e tre le tipologie di dati è il livello medio del mare.

La correzione per il terreno calcolata per i dati di gravità può essere significativa in quanto varia tra 0 e 8,6 mGal.

2.2 Prospezione magnetica

2.2.1 Dati acquisiti

Sono state acquisite 315 stazioni magnetiche, coincidenti nella posizione con quelle gravimetriche, in seguito riportate su tutti gli elaborati cartografici con dei triangoli gialli.

I dettagli relativi alle operazioni di rilevamento magnetico sono riportate nei rapporti della Geoinvest e della AOA Geophysics.

A causa dell'elevata densità di popolazione nell'area è stata usata molta cura nella scelta della stazione-base magnetica, posta in un luogo piuttosto isolato dalle attività umane e, in questo caso, subito al di fuori dell'area del permesso. Il magnetometro usato è stato il modello a protoni Geometrics Model G856.

Il rilevamento è stato eseguito da un unico operatore e in tempi diversi da quello gravimetrico.

2.2.2 Procedure di elaborazione

Delle procedure di riduzione sono state applicate ai dati magnetici acquisiti dal programma; queste includono:

a) cancellazione di valori spuri misurati nelle stazioni ripetitrici
b) media ponderata dei valori raccolti dalle stazioni riceventi
c) correzione diurna
d) correzione IGRF

Il campo magnetico misurato e mappato (mappa delle anomalie TMI – Total Magnetic Intensity, fig.7) è però fortemente falsato dalle anomalie magnetiche causate da numerose sorgenti a bassa lunghezza d'onda presenti vicino alla superficie, che l'AOA Geophysics ha cercato di filtrare.

I dati di anomalia TMI hanno subito la riduzione al polo, per produrre una mappa delle anomalie che siano localizzate direttamente sulle loro cause geologiche, rimuovendo l'effetto deviatorio del campo geomagnetico principale della Terra (fig.8) e in seguito corretti applicando un secondo operatore derivativo verticale (fig.9).

2.3 Prospezione magnetotellurica (MT)

2.3.1 Breve riesame del MT

MT è un metodo geofisico passivo, che utilizza l'energia elettromagnetica a bassa frequenza per determinare la resistività elettrica nel sottosuolo. Con questo metodo è possibile distinguere i vari tipi di rocce e i fluidi di formazione sulla base dei loro valori di resistività. Nel caso in cui vi sia presenza di olio o gas, questi non vengono riconosciuti immediatamente, ma vengono localizzate delle zone a bassa resistività o dei contrasti di resistività riconducibili a delle rocce serbatoio. Questo metodo, integrato ai dati sismici, è stato usato principalmente nelle aree sede di sovrascorrimenti dove gli obiettivi sono le sequenze clastiche a bassa resistività poste al di sotto di formazioni più resistive.

Gli obiettivi principali del programma MT nel permesso Caserta possono essere così riassunti:

a) Stimare lo spessore dei carbonati (ad alta resistività) che affiorano nelle porzioni orientali ed occidentali del permesso
b) Determinare la resistività e quindi i tipi di litologie presenti tra i carbonati affioranti e, in particolare, verificare l'eventuale presenza di carbonati a basse profondità. Questa parte della sezione geologica potrebbe includere sia i sedimenti clastici e carbonatici appartenenti al gruppo del Lagonegro, sia flysch più giovani.
c) Stimare la profondità della Piattaforma carbonatica Apula.

2.3.2 Acquisizione dati

I dati MT sono stati acquisiti su 20 siti distribuiti nelle ampie valli e sulle colline ove iniziano ad affiorare i carbonati e sono indicati da triangoli magenta su tutti gli elaborati cartografici prodotti. I dati sono stati acquisiti con un range a larga frequenza per determinare la resistività sia di sezioni superficiali, sia profonde.

I dettagli operativi del programma investigativo sono riportati sul rapporto di campagna della Geoinvest e della AOA Geophysics ed allegato al presente rapporto.

2.3.3 Procedure di elaborazione

I dati rilevati sono stati processati inizialmente dalla Geoinvest e in seguito dalla AOA usando la work station Geotools MT.

Le procedure di Geoinvest includono:

a) decimazione e ricampionamento delle serie temporali dei campi magnetico ed elettrico registrati
b) analisi delle serie temporali banda-a-banda e selezione dei segmenti coerenti-dipendenti
c) "robust processing" per rimuovere i domini tempo-frequenza dei dati ricavati da punti esterni all'area o esclusi dal campionamento
d) creazione di un tensore d'impedenza e di un cross-power a larga banda combinando le singole bande di frequenza
e) rappresentazione di dati per scopi QC
f) creazione di file EDI per trasferire i dati alla work station Geotools MT

Le procedure di AOA includono:

a) calcolo delle funzioni MT
b) analisi iniziale e compilazione dei risultati
c) analisi statistica e designazione delle correzioni
d) eliminazione statica dove giustificato
e) compilazione finale dei dati
f) preparazione del database finale e generazione di plots di dati.

2.4 Prospezione geochimica

2.4.1 Acquisizione dati

I campioni geochimici sono stati acquisiti in 205 luoghi utilizzando dei Gore-Sorbers che sono dei moduli campionatori passivi utilizzati per le indagini geochimiche di superficie installati nel terreno e recuperati dopo circa 15 giorni. Sono stati installati in buchi stretti (la cui ubicazione è stata determinata con il GPS) realizzati con un apposito martello e localizzati lungo le linee delle prospezioni magnetiche e gravimetriche alla distanza di circa 1Km l'uno dall'altro.

2.4.2 Procedure di elaborazione

Le procedure di elaborazione dei dati hanno incluso:

a) analisi statistica dei campioni di gas del suolo con i metodi HCA (Hierarchical Cluster Analysis) e DA (Discriminant Analysis)

b) determinazione dei tipi di idrocarburi mediante comparazione con campioni ripresi da pozzi e altri siti prescelti presenti nell'area; in questo caso non essendoci pozzi nell'area sono stati presi a campione due pozzi presenti in aree limitrofe: Monte Taburno 1 e Morcone 1.

3. INTERPRETAZIONE INTEGRATA STRUTTURALE - STRATIGRAFICA

3.1 Geologia Regionale

Il permesso Caserta si trova circa 30 km a nord di Napoli, ad est degli edifici vulcanici del Vesuvio e di Roccamonfina. Lo schema tettonico degli Appennini è ormai ben noto: delle falde di Liguridi sono sovrascorse su termini di piattaforma carbonatica di età da Triassica ad Eocenica che a loro volta sono inseriti, insieme a termini di bacino coevi, in falde che si accavallano su una piattaforma più orientale (Apula) affiorante nel Gargano, ed anch'essa coinvolta in profondità nel sistema a thrusts verso occidente. Diverse sequenze clastiche sin-orogeniche di età miocenica sono coinvolte nel sistema in movimento verso E, insieme ai bacini di piggy-back e a quelli estensionali che si formano sul retro delle strutture accavallate. Il permesso è localizzato internamente a questo sistema, dove la piattaforma carbonatica Appenninica, le rocce del bacino di Lagonegro e il flysch sin-orogenico dominano negli affioramenti, tutti in accavallamento verso la piattaforma Apula posta ad E ed immergente verso W.

Un fattore importante di questa zona è dato dall'impronta dell'estensione Plio-Pleistocenica relazionabile all'apertura del Tirreno e all'associato vulcanismo (i bordi della caldera che contiene Roccamonfina affiorano nel margine occidentale del permesso e numerose faglie normali nascondono l'azione dei sovrascorrimenti). La piattaforma carbonatica affiora nei rilievi del Casertano e giace sopra il flysch nei settori centrale e meridionale del permesso, fortemente influenzati da deformazione estensionale. La valle del Volturno separa il rilievo del Monte Maggiore dai Monti del Matese ancora appartenenti alla piattaforma Appenninica, affiorante a NE del permesso, e poi taglia verso W a separare il rilievo del Monte Maggiore da quello del Casertano e quindi procede verso il Tirreno.

Il pozzo Morcone 1, perforato subito al di fuori dell'area ha permesso la conoscenza degli spessori di molte delle unità Mesozoiche presenti nel blocco. Le linee sismiche BN-316-85-PX e BN-308-85-PX pur non essendo particolarmente indicative sull'assetto geologico sepolto dell'area indicano che la valle del Volturno è strutturalmente controllata, bordata a NE dai sovrascorrimenti del Matese SE-vergenti e a SW da un sistema di faglie normali che tagliano i thrusts NE-vergenti del Monte Maggiore. Alla luce di quanto detto, la ricerca si è accentrata nella valle del Volturno.

Il campo produttivo più vicino all'area in esame è quello di Benevento che produce olio dai carbonati mesozoici, al di sotto del Flysch Messiniano.

3.2 Sezioni geologico-strutturali

Due sezioni geologiche sono state ricostruite utilizzando i seguenti dati:

a) i fogli geologici, alla scala 1:100.000, *172 Caserta* e *173 Benevento*

b) i logs dei pozzi Morcone 1 e 1bis

c) la topografia ripresa dal DEM di AOA

d) le linee sismiche BN316-85-PX e BN-308-85-PX

e) i profili gravimetrici, magnetici e MT del modello strutturale di AOA

La sezione A-A' mostra alcuni alti strutturali nelle rocce cretaciche e giurassiche della piattaforma appenninica nella valle del Volturno, parzialmente obliterate dal raccorciamento del sistema Appenninico in accavallamento; la sezione B-B' mostra un altro alto strutturale, più grande, tagliato da faglie normali. In entrambe le sezioni è stata assunta: una superficie di scollamento alla profondità di 5,5 Km e anche di più; alle geometrie a thrusts si è sovrimposta una deformazione estensionale neogenica.

3.3 Discussione del Play

Le rocce madri per i campi posti nei settori interni dell'Appennino sono generalmente carbonati Triassici e Liassici. I reservoirs sono probabilmente ubicati nei carbonati mesozoici tamponati da flysch miocenici. La migliore opportunità nel blocco Caserta è data dalle strutture nella valle del Volturno, dove sia le strutture da accavallamento sia gli alti strutturali sottoposti ad azione distensiva sono tamponati dal flysch e in buona posizione per intrappolare idrocarburi generati in profondità dalle rocce madri Triassico-Giurassiche.

Il gas biogenico è generato dalle unità terrigene plio-pleistoceniche più superficiali, ma i campi sono generalmente ubicati nel Mare Adriatico.

3.4 Discussione dell'interpretazione integrata

3.4.1 La depressione del Volturno – Possibili vie favorevoli all'esplorazione

I dati gravimetrici e MT indicano un buon trend sedimentario suscettibile di esplorazione nella valle del Volturno situata nelle porzioni settentrionali e orientali del permesso Caserta; questo trend è caratterizzato da potenti sequenze clastiche terziarie e da flysch soprattutto nella porzione settentrionale.

I dati MT indicano la presenza di un'unità sedimentaria di natura calcarea, a media resistività, nella valle del Volturno, simile dal punto di vista elettrico ad un contatto a media resistività osservato in Val d'Agri che si correla alle facies bacinali del Lagonegro.

La valle del Volturno presenta una pronunciata anomalia di gravità la cui estensione è ben delineata da un trend di minimo nella mappa della anomalia di gravità isostatica (fig.10), a causa della bassa densità dei depositi che riempiono la valle e delle unità clastiche adiacenti. Anche la mappa del campo di gravità regionale mostra un'anomalia coincidente con la valle del Volturno (fig.11) mentre in quella dell'anomalia di Bouguer (fig.6) il contrasto è meno evidente a causa dell'effetto oscurante del gradiente di gravità regionale dovuto alla Moho.

Sebbene non vi siano informazioni sulla densità di volume delle rocce sedimentarie presenti nel sottosuolo del permesso, da dati di pozzi limitrofi (Benevento sud 1 e Circello 1) sembra che i carbonati della piattaforma Appenninica siano simili a quelli della piattaforma Apula per quanto riguarda le caratteristiche di densità. Così esiste un contrasto di densità tra l'interfaccia dei calcari appenninici sepolti e le sequenze clastiche, il flysch o le facies carbonatiche di bacino che le ricoprono.

La mappa di anomalia di gravità residua (fig.12) e quella della gravità verticale derivata mostrano con maggior dettaglio gli andamenti in prossimità del depocentro della valle.

3.4.2 Sezioni gravimetriche/magnetiche/MT del modello strutturale

Sono state ricostruite sette sezioni (A-G), realizzate allo scopo di determinare i principali elementi strutturali presenti nel permesso Caserta; l'ubicazione delle sezioni è riportata nella mappa del modello gravimetrico 3D della profondità stimata al top dei carbonati (fig.14). La sezione A ha lo scopo di mostrare la Valle del Volturno e di creare un collegamento con le altre sezioni.

I risultati dell'interpretazione del programma MT sono stati proiettati nelle sezioni profonde del modello gravimetrico e magnetico per indicare i contrasti di densità tra le sequenze clastiche e il flysch, meno resistivi, i carbonati della Piattaforma Appenninica, più resistivi e le sequenze bacinali (Lagonegro) a resistività intermedia. Il modello include varie tracce di faglia, ricavate dalla geologia di superficie, al fine di determinare uno stile geologico per il blocco Caserta; dall'indagine MT è stata inoltre evidenziata la presenza di una superficie di scollamento a 5,5 km di profondità in prossimità probabilmente del top della piattaforma Apula.

3.4.3 Elementi strutturali nell'area della depressione del Volturno

<u>Sezione gravimetrica/magnetica/MT A (fig.17)</u>

Questa sezione è orientata perpendicolarmente al trend tettonico ed è stata scelta per evidenziare la depressione del Volturno e funge da collegamento per le altre sezioni.

Sezione gravimetrica/magnetica/MT B (fig.18)

Illustra la depressione del Volturno larga da 5 a 10 Km, che viene interpretata come riempita da sedimenti clastici/flysch, a bassa densità, fino a 5,000m di profondità posti al di sopra di rocce carbonatiche più dense e resistive. Un valore di resistività medio-alto è stato rilevato ed indicherebbe la presenza di facies carbonatiche di bacino (Lagonegro). Dalla sezione è possibile verificare la presenza verso occidente di più sovrascorrimenti dei termini carbonatici appenninici e di unità clastiche nonché l'immersione dei carbonati verso l'area sud-occidentale del permesso.

Sezione gravimetrica/magnetica/MT C (fig.19)

Si presenta sostanzialmente simile alla linea precedente, ma mostra anche lo sviluppo di un sistema in accavallamento vergente a NE, con il sovrascorrimento di una sottile placca Appenninica sopra una presunta sequenza clastica spessa circa 1 km. L'elemento più importante di questa linea è una struttura positiva, ad alta densità e resistività, che emerge dal fondo della depressione del Volturno e che viene interpretata come top dei carbonati Mesozoici, NE vergenti che potrebbero essere stati caricati con idrocarburi.

Sezione gravimetrica/magnetica/MT D (fig.20)

Attraversa la valle del Volturno con le sequenze clastiche di riempimento e identifica uno spessore di rocce carbonatiche di bacino spesse 2.500m a media resistività e assimilabili alle unità del Lagonegro. Di rilievo è la presenza di una struttura a pop-up formata da un blocco Mesozoico, che offre una chiusura strutturale per l'accumulo di idrocarburi. Ancora una volta è verificato l'accavallamento NE vergente delle unità della falda appenninica su una presunta sequenza clastica.

Sezione gravimetrica/magnetica/MT E (fig.21)

Il profilo mostra nella sua parte finale verso NE degli accavallamenti Appenninici vergenti a SW, una struttura carbonatica che emerge dal fondo della depressione del Volturno e una diminuzione nello spessore del riempimento clastico della valle del Volturno verso S in direzione della parte orientale del permesso. Un aumento del campo magnetico viene rilevato nella porzione centrale del profilo a testimoniare un innalzamento del basamento igneo sottostante.

Sezione gravimetrica/magnetica/MT F (fig.22)

Evidenzia numerose strutture appenniniche positive nella depressione del Volturno, e la vergenza verso SW di una falda Appenninica che sovrascorre su unità di flysch. Questa sezione mostra più delle altre le variazioni strutturali nel basamento igneo sottostante che si ritiene influenzi l'opposta vergenza della placca appenninica nel settore nord-orientale del permesso.

Sezione gravimetrica/magnetica/MT G (fig.23)

Ricalca sostanzialmente la sezione F; in essa viene rilevata una diminuzione nello spessore dei sedimenti di riempimento della Valle del Volturno (2.000m).

3.4.4 Discussione dei risultati geochimici

I risultati delle analisi dei campioni raccolti evidenzia la presenza di alcuni elementi geochimici di media entità in tutta l'area del permesso, tranne che nel settore centrale. L'area più interessante sembra essere quella relativa al settore nord-occidentale del permesso (fig.24). Basse probabilità di accumuli si hanno nelle unità carbonatiche affioranti del M. Maggiore, in linea con quanto risulta dalle analisi dei dati di gravità e MT, mentre molto più interessante è l'area della Valle del Volturno giusto al margine dell'affioramento della falda più esterna del sovrascorrimento del M. Maggiore. La possibile migrazione a giorno di idrocarburi nella valle, è apparentemente facilitata dall'assenza, di una barriera al di sopra dei carbonati massivi Appenninici, ed inoltre una possibile roccia madre può essere presente nella depressione del Volturno.

4. CONCLUSIONI SULLE POTENZIALITA'

Un interessante trend sedimentario, costituito da spesse sequenze clastiche Terziarie e da flysch, è stato evidenziato dai dati gravimetrici e MT nelle porzioni settentrionali e orientali del permesso Caserta, proprio in coincidenza con l'attuale Valle del Volturno. Questo trend continua verso il bordo meridionale del permesso con un asse passante per il paese di S.Agata dei Goti. Il massimo spessore dei terreni clastici si ha nei pressi del paese di Alife.

Molte strutture sepolte di età Mesozoica emergono, in profondità, al di sotto della valle e potrebbero appartenere sia al dominio Appenninico che a quello Apulo.

Le rocce madri per i campi ubicati nella zona interna degli Appennini sono generalmente assimilabili a rocce carbonatiche di età tardo Triassica e Liassica, mentre il gas biogenico è generato dalle unità terrigene più superficiali.

I reservoirs dovrebbero essere presenti nei carbonati Mesozoici, mentre il sealing è rappresentato dal flysch Miocenico.

Delle analogie con la Val d'Agri fanno si che l'area del permesso sia interessante dal punto di vista del potenziale petrolifero ed in modo particolare l'area della depressione del Volturno dove coesistono elementi strutturali legati a sovrascorrimento e alti strutturali dovuti ad azione distensiva.

La roccia madre è Triassico-Giurassica, in analogia a tutti i campi ad olio dell'Appennino Meridionale, anche se non si può escludere una source più profonda come la Piattaforma Apula.

Le strutture presenti nella depressione del Volturno appaiono ben tamponate dal flysch e dai sedimenti clastici post-orogenici che riempiono la valle; infine i dati di MT hanno permesso di stabilire che sedimenti equivalenti a quelli di bacino (Lagonegro) hanno contribuito all'azione di intrappolamento di potenziali idrocarburi presenti nell'area.

FINAL REPORT

1999 EXPLORATION PROGRAM

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Isostatic Gravity Anomaly Map
Regional Gravity Anomaly Map
Residual Gravity Anomaly Map
Vertical Derivative of Residual Gravity Anomaly Map
Total Magnetic Intensity (TMI) Anomaly Map
Reduced-to-Pole (RTP) Magnetic Anomaly Map
Second Vertical Derivative of RTP Magnetic Anomaly Map
Surface Geology & Regional Gravity Map
Surface Geology & RTP Magnetic Anomaly Map
3-D Gravity Model Estimation of Depth to Carbonate
3-D Gravity Model Estimation of Depth to Carbonate with Superimposed Gore-Sorber Petroliferous Probability Results

1:50,000 Structural Geology Cross-Sections

GRANATH & Associates Structural Geology Cross-Section A-A'
GRANATH & Associates Structural Geology Cross-Section B-B'

1:50,000 Gravity/Magnetic/MT Structural Model Cross-Sections

Profile A
Profile B
Profile C
Profile D
Profile E
Profile F
Profile G

FINAL ARCHIVE DIGITAL GRIDS

Map Projection Information:
  Projection System: Universal Transverse Mercator
  Reference Datum (and Ellipsoid): WGS84
  Central Meridian: 15° East (UTM Zone 33 north)
  Latitude Of Origin: 0°
  Scale Factor: 0.9996
  False Easting: 500,000 Meters
  False Northing: 0 Meters

Final project digital grid files are delivered in a sequential ASCII flat-file format, with one grid node sample per record. Each grid node sample is written with five fields of information as:

Longitude (Decimal Degrees)
Latitude (Decimal Degrees)
UTM-Easting (Meters)
UTM-Northing (Meters)
Grid Z-Value

Dummy (a.k.a. ZNON, ZBAD, ZNUL, etc.) values are trimmed from the final digital grid files. Original grid parameters (prior to dummy-value trimming) are:

XMIN = 428,000 Meters
XMAX = 465,000 Meters
YMIN = 4,540,000 Meters
YMAX = 4,580,000 Meters
Grid X-Increment = 250 Meters
Grid Y-Increment = 250 Meters
Number Of Grid Rows = 161
Number Of Grid Columns = 149

An exception to the above is the terrain data grid, which differs in having an x and y grid increment of 20 meters, and 1851 grid columns and 2001 grid rows.

The various delivered grids are identified as follows:

Full-Size (1 : 50,000) Mapped Data Grids

terrain.XYZ	Merged Terrain (meters). Sea level reference.
free-air.XYZ	Free-Air Gravity Anomaly (mGal). 1998 NIMA gravity reference model used.
boug-263.XYZ	Bouguer Gravity Anomaly (mGal). 2.63 g/cc reduction density used for Bouguer and terrain corrections.
isog.XYZ	Airy-Heiskanen Isostatic Regional Gravity Anomaly (mGal). Assumed crustal thickness at sea level is 29 KM. Upper Mantle Density: 3.27 g/cc Lower Crustal Density: 2.84 g/cc Onshore Upper Crustal Density: 2.50 g/cc Offshore Upper Crustal Density: 2.20 g/cc Sea Water Density: 1.03 g/cc
isog-reg.XYZ	Regional Gravity Anomaly (mGal). 16 KM Butterworth low-pass filter applied to the isostatic gravity anomaly.
isog-res.XYZ	Residual Gravity Anomaly (mGal). 16 KM Butterworth high-pass filter applied to the isostatic gravity anomaly.
isog-rvd.XYZ	Vertical Derivative of Residual Gravity Anomaly (mGal/m).
tmi.XYZ	Total Magnetic Intensity (TMI) Anomaly (nT).
rtp.XYZ	Reduced-To-Pole (RTP) Magnetic Anomaly (nT).

1999 EXPLORATION PROGRAM

CASERTA PERMIT
CAMPANIA, ITALY

FINAL REPORT

1. Introduction

1.1 Objectives of the Non-Seismic Field Program

During late October, November and early December 1999 gravity, magnetic, magnetotelluric (MT) and surface geochemistry surveys were performed for Forest Oil International on the Caserta Permit in south central Italy (Figures 1 to 4). The geophysical and geochemical results were then integrated with a geologic study of the area to provide Forest with an evaluation of the prospectivity of the permit and recommendations for further work.

The survey program was designed to provide a cost effective evaluation of the permit with the objective of first, determining the overall prospectivity of the area through the application of an integrated geophysical-geochemical-geologic approach, and then to identify prospective leads for future, more intensive exploration. While there are no oil/gas wells on the permit, with the nearest sub-surface data several kilometers to the east and northeast, central and southern Italy is an active hydrocarbon exploration area. There have been prolific discoveries in geologic settings similar to that of the Caserta Permit for both shallow and deep targets, thus the motivation for this integrated exploration program.

The southern and central Apennines are difficult areas for seismic exploration. The non-seismic exploration tools employed by Forest provide initial reconnaissance and prospect-specific data, upon which exploration decisions can be made. The objective of acquiring gravity data was to take advantage of the density contrast between the carbonate and flysch/clastic formations as an aid to identifying larger scale tectonic features as well as providing important constraints to the interpretation of the available seismic data. Magnetic data were acquired as an aid to identifying possible volcanic intrusive bodies, in an area with known volcanic activity (Mt. Vesuvius can be seen from the permit). Magnetotelluric (MT) data were acquired to take advantage of the technique's ability to identify clastic units beneath overthrust carbonates, and to augment the gravity data in so far as providing further insight into the lithology of the shallower section. Geochemical data were acquired using a relatively new sophisticated technology to determine if there is any evidence for the presence of hydrocarbons that might reflect subsurface accumulation.

The objectives of the program were met by first acquiring and processing geophysical and geochemical data of the highest quality and then performing an integrated geophysical/geologic interpretation taking advantage of the strengths of each individual component. The results are presented on a series of maps and cross-sections.

1.2 Overview of the Exploration Program

The terrain over the permit consists largely of relatively flat valleys and gently rolling hills with a few steeper topographic features. Access to most portions of the area is straight-forward allowing good data coverage entirely with paved or farm road access. The area is one of numerous farms and villages, but these did not materially affect survey design or operations.

Gravity, magnetic and geochemical data were acquired along secondary roads and farm tracks, with the survey designed as a series of northeast-southwest and northwest-southeast trending profiles. MT data were acquired at locations selected on the basis of the interpretation of available seismic data, the desire to determine if deeper exploration targets are present beneath the shallow Apennine carbonates, and surface geology. No problems were encountered in data acquisition or processing of the geophysical and geochemical data.

The geophysical data were acquired by Geoinvest SRL of Piacenza, Italy under the supervision of AOA Geophysics Inc. staff geophysicists. Initial data processing was performed by Geoinvest, and final data processing and interpretation were performed by AOA. Geoinvest was also responsible for deployment and retrieval of the geochemical sensors, Gore-Sorbers, which were sent to W. L. Gore & Associates, Inc. for analysis.

Details of the geophysical and geochemical data acquisition are included in the operations reports (AOA Geophysics and Geoinvest SRL, 2000 ; W. L. Gore & Associates, 2000) submitted to Forest.

2. Geophysical/Geochemical Program

2.1 Gravity Survey

2.1.1 Data Acquired

320 gravity stations were successfully acquired as part of the 1999 Caserta Block non-seismic geophysics field program. Locations of the newly acquired gravity stations are indicated by the blue-colored circle symbols which appear on all project maps. Station distribution can be seen, for instance, on the terrain and surface geology maps (Figures 1 and 2 respectively).

Comprehensive details regarding the 1999 gravity survey operations are documented in the survey operations report (AOA Geophysics and Geoinvest SRL, 2000) and in the survey principal facts (Geoinvest SRL, 1999). In addition, various aspects of the gravity field program are discussed in the article by Pawlowski (2000), which is included as Appendix 1 of this report. Hence gravity survey details will be discussed only briefly here.

Gravity stations were laid out in order to take advantage of the existing well-developed network of roads within the permit, and also to optimize geophysical coverage of the block itself - this in keeping with the reconnaissance nature of the field program. A more or less regular in-line gravity station spacing of 500 meters was maintained during the survey.

Before gravity survey measurements commenced, stations were surveyed and tied to official topographic bases of the Istituto Geografico Militare (IGM). Station surveying was performed using GPS. All details pertaining to station surveying are contained in the survey operations report (AOA Geophysics and Geoinvest SRL, 2000). The vertical accuracy of +/- 10 cm in surveyed station elevations is more than adequate for reconnaissance surveying of principal structures (e.g., an error in surveyed elevation of 10 cm translates to an error in reduced gravity of only 0.03 mGal).

Terrain in the vicinity of each gravity station (Hammer zones B, C, and D) was surveyed using a reflectorless laser rangefinder - this for the purpose of later making near-zone gravity terrain correction computations.

Gravity readings were made in consistent fashion by the same operator using a LaCoste & Romberg Model G Gravity Meter (L&R Model G Meter Number 697). No problems were experienced related to gravity meter performance (i.e., minimal meter drift, no tares). Three local gravity base stations were established in the survey area. These local bases permitted all surveyed gravity values to be related (tied) to the two official absolute gravity networks used in Italy, the International Gravity Standardization Net (IGSN-1971), and the Rete Gravimetrica Fondamentale Italioana (RGFI-1955).

In addition to the newly acquired gravity data, 508 absolute gravity station values from the Caserta project area were acquired via the open file data repository of NIMA (U.S. Government's National Imagery and Mapping Agency). These data were used to augment the 1999 proprietary data acquired within the block, and also provided an important regional gravity field constraint on the interpretation of those areas either near the edge of or just outside of the Caserta Block boundary. Locations of the NIMA open file gravity stations are indicated by the red-colored circle symbols which appear on all project maps.

2.1.2 Processing Procedures

Standard and consistent gravity reduction procedures were applied to data from both the 1999 proprietary survey program and the NIMA open file gravity data. Data reduction procedures applied by Geoinvest to the proprietary survey data in order to obtain absolute gravity values are fully documented in the survey operations report (AOA Geophysics and Geoinvest SRL, 2000) and in the survey principal facts (Geoinvest SRL, 1999).

The final processing procedures applied by AOA Geophysics to the Geoinvest and NIMA absolute gravity values include:

a) Theoretical gravity correction (1998 NIMA formula), including an atmospheric gravity correction

b) Standard free-air correction (0.3086 mGal/m)

c) Simple Bouguer slab correction (2.63 g/cc reduction density)

d) Hammer zone (1981 Hammer zone chart) terrain correction (2.63 g/cc reduction density)

Application of the above procedures yielded final processed free-air gravity anomaly (Figure 5) and complete Bouguer gravity anomaly (Figure 6) values for each gravity station. A measure of the reliability of the open file NIMA gravity data is the fact that the NIMA free-air gravity anomaly data merged cleanly with the 1999 field program gravity data. No level-shifting or other corrections were required to merge the NIMA free-air anomaly values with the 1999 field program free-air gravity anomaly data.

The complete Bouguer anomaly reduction density of 2.63 g/cc was arrived at through consideration of the surface geology in the project area, and also through the technique known as Nettleton-profiling. The abundance of terrain-forming Apennine carbonate units, as well as the calcareous sediments filling the local valleys in the project area, results in fairly high average (or bulk volume) densities of the rock units between the ground surface and sea level. Nettleton profiling indicates that a reduction density of 2.63 g/cc minimizes the correlation between the Bouguer gravity anomaly and topography.

A highly detailed digital terrain model was constructed for the purpose of computing accurate gravity terrain corrections. Three different sources of digital terrain data were employed for terrain correction purposes:

a) Within 60 meters of station: Laser rangefinder data

b) Within 60 to 10,000 meters of station: IGM 20-meter DEM data

c) Beyond 10,000 meters of station: GTOPO30 1-minute DEM data

Vertical datum reference for all three of the above data sets is mean sea level. The IGM 20-meter DEM data does not provide coverage for all of the open file NIMA gravity stations outside of the Caserta Block. Also, laser rangefinder data obviously only exist for stations belonging to the proprietary 1999 program. For these latter cases, GTOPO30 1-minute DEM data only was used.

A measure of the quality of the IGM 20-meter DEM data can be obtained by comparing it with the 1999 field program GPS-acquired gravity station elevations (converted to mean sea level) and their associated near-station laser rangefinder elevations. The mean difference between the 1999 field program elevations and IGM 20-meter DEM elevations is -0.5 meters, or practically zero, with a standard deviation of only 5.9 meters. The maximum elevation difference is 39.7 meters, while the minimum difference is -56.9 meters. The accuracy of the IGM 20-meter DEM data thus appears to be quite high.

Computed terrain corrections for the project area gravity data can be significant, ranging from effectively zero to as large as 8.6 mGal.

2.2 Magnetic Survey

2.2.1 Data Acquired

315 magnetic stations were successfully acquired as part of the 1999 Caserta Block non-seismic geophysics field program. Locations of the newly acquired magnetic stations are indicated by the yellow-colored triangle symbols which appear on all project maps. Station distribution can be seen for instance, on the terrain and surface geology maps (Figures 1 and 2 respectively). All of the acquired magnetic stations are coincident in location with gravity stations (discussed above).

Comprehensive details regarding the 1999 magnetic survey operations are documented in the survey operations report (AOA Geophysics and Geoinvest SRL, 2000) and in the survey principal facts (Geoinvest SRL, 1999). Hence magnetic survey details will be discussed only briefly here.

The Caserta Permit is a noisy environment for ground magnetic survey operations - this because of the numerous towns, farms, and roads - all with their attendant noise problems resulting from man-made ferrous objects and electrical power lines. Care was thus taken to establish the magnetic base station in the most culturally quiet area possible. Several locations for the base station were tested before a suitably quiet location was found just outside of the southeastern block boundary, near the town of Paolini. The base station magnetometer employed was a Geometrics Model G856 proton precession magnetometer.

The magnetic survey was conducted separately from the gravity survey. In this manner, the magnetometer operator had the flexibility (since gravity meter drift was no longer an issue) to experiment with locating the point of measurement slightly away from the surveyed station when the latter was too close to interfering ferrous objects or electric fields. All magnetic readings were made by the same operator using a Geometrics Model G856 proton precession magnetometer.

2.2.2 Processing Procedures

Standard and consistent magnetic data reduction procedures were applied to the magnetic survey data, and these are fully documented in the survey operations report (AOA Geophysics and Geoinvest SRL, 2000) and in the survey principal facts (Geoinvest SRL, 2000). The data processing procedures included:

a) Deletion of spurious measured repeat-station values

b) Statistical weighting of accepted measured repeat-station values

c) Diurnal correction

d) IGRF correction

Additional editing and trend surface filtering was applied by AOA Geophysics in an attempt to maximize the line-to-line correlation of mapped magnetic anomalies. The result of this effort can be seen in the TMI (Total Magnetic Intensity) anomaly map of Figure 7. In spite of these procedures, reliable mapping of the Caserta Permit magnetic anomaly field is difficult due to the limited sampling (315 magnetic stations) of the magnetic field relative to the numerous sources (cultural and near-surface geologic) of short wavelength magnetic anomalies. In other words, the observed and mapped magnetic anomaly field is highly aliased.

The TMI anomaly data were reduced to pole (Figure 8) and further residualized through application of a second vertical derivative operator (Figure 9). Reduction-to-pole is a filter-based transformation whose purpose is to produce a magnetic anomaly map with anomalies more directly located over the causative geologic features - thus removing the skewing effect of the Earth's inclined geomagnetic field (so-called main field or dipole field) (inclination and declination approximately 57.4° north and 1.5° east respectively in the permit area).

2.3 Magnetotelluric Survey

2.3.1 Brief Review of MT

MT is a passive geophysical method, utilizing naturally occurring low frequency electromagnetic energy to determine the electrical resistivity of the subsurface. MT has the capability of measuring the resistivity of the earth from the very near surface to depths at and beyond those of exploration interest.

A knowledge of the earth's resistivity as determined through the use of MT is important since rock types and formation fluids important to the interpretation of subsurface geology can be differentiated on the basis of resistivity value. Thus, a resistivity-versus-depth cross-section of the earth can be broadly interpreted in terms of rock type, and spatial variations in the resistivity-depth relationship observed at closely spaced locations on the surface can be interpreted in terms of subsurface geologic structure. As used for oil and gas exploration the MT method cannot detect oil or gas directly, but can be used to locate zones of low resistivity or resistivity contrast which may be related to source and reservoir rocks and favorable structure.

MT data are acquired where the exploration objectives involve geologic units of contrasting resistivity. The method has probably been used most commonly for exploration in carbonate, volcanic, and overthrust areas around the world, where the targets are lower resistivity clastic sediments or zones of relatively higher porosity within and beneath more resistive formations. Seismic data quality is often poor beneath massive carbonates, in volcanic, and in carbonate or hard rock overthrust areas, and the MT data can form an important part of the geophysical data base. The method is also useful under difficult terrain conditions or over large unexplored areas where seismic data quality is expected to be good, but seismic data acquisition is either very expensive or many kilometers are required to characterize the area. In such situations an MT survey can demonstrate the validity of a geologic concept, and/or assist in laying out a cost-effective seismic program limited to the actual target or targets. In general, very detailed geologic investigations such as locating a structural location to drill is not an MT application unless the MT data are integrated with other geophysical and geologic information. This was the approach used for the Caserta program.

The specific objectives of the Caserta MT survey may be summarized as follows:

1. To estimate the thickness of the high resistivity Apennine carbonates that outcrop in the western and extreme eastern portions of the permit.

2. To determine the resistivity and thereby infer the lithology of the section between the outcropping carbonates, in particular to determine if shallow carbonates are present. This portion of the geologic section may include the clastics and carbonates of the Lagonegro group as well as younger flysch units.

3. If possible, and if geologic conditions permit, to estimate the depth to the high resistivity Apula carbonate platform.

2.3.2 Data Acquired

MT data were acquired at 20 locations. Locations were distributed in the broad valleys, and on the hills where primarily carbonate outcrops. Locations of the MT stations are indicated by the magenta-colored triangle symbols which appear on all project maps. One of the locations (MT site CA11) was placed to the east of the permit in order to determine if the deep Apula platform could be identified and a depth to the top of the platform carbonates determined. Data were acquired over a broad frequency range in order to determine the resistivity of both the shallow and deep section.

Details of the MT data acquisition are contained in the Operations Report submitted to Forest (AOA Geophysics Inc. and Geoinvest SRL, 2000).

2.3.3 Processing Procedures

The data processing and preliminary analysis sequence is listed below. Data processing was accomplished in two stages: First, the acquisition contractor (Geoinvest) performed the basic processing which included standard and robust processing procedures[1]. Then the data were further processed by AOA using the Geotools MT work station.

1. Geoinvest processing:

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[1] The term "Robust processing" is used to denote algorithms which identify and remove time and/or frequency domain outliers and invalid data points, and which take maximum advantage of the clean (noise-free) reference signal to optimize the signal to noise ratio and thus data quality.

a. Decimation and re-sampling of the recorded electric and magnetic field time series

b. Band-by-[frequency] band time series analysis and coherency-dependent segment selection

c. Robust processing

d. Creation of the broad-band cross-power and impedance tensor files by combining the individual frequency bands

e. Generation of data plots for QC purposes

f. Generation of the EDI file (SEG standard format) for data transfer to the Geotools MT work station

2. AOA Geotools MT processing (from cross-power or impedance tensor data in EDI format, as delivered by Geoinvest):

   a. Computation of MT functions

   b. Initial analysis and edit

   c. Statics analysis and assignment of corrections

   d. Statics stripping where warranted

   e. Final edit

   f. Preparation of final data base and generation of data plots.

At this stage the data were ready for modeling and inversion, and the final interpretation and integration.

2.4 Geochemical Survey

2.4.1 Data Acquired

Geochemical samples were acquired at 205 locations utilizing Gore-Sorbers. The Sorbers are passive sampler modules used for surface geochemical surveys. The field work consisted of the installation of the Sorbers in the ground and then retrieving them after 15 to 17 days. The survey design and the instructions for handling and installing the Sorbers came directly from the European Gore representative in Germany.

The Sorbers were installed in a narrow pilot hole that was made utilizing a special hammer provided by Gore. The sample locations were located using GPS and were marked by placing a small red flag attached to a tree or to a stake. Any other nearby identifying features were noted on a field sketch to ease recovery if the flag should disappear. The position was also recorded in the GPS receiver.

As planned by Gore the Sorbers were installed along the gravity/magnetic survey lines and on two wells for calibration. Sorber location density along the profiles was approximately one per kilometer, half of the density of the gravity and magnetic survey. Locations of all Sorber installations are tabulated in the report submitted by Gore to Forest (W. L. Gore & Associates, Inc., 2000). After retrieval the Sorbers were sent to the Gore laboratories in Maryland for analysis.

Additional detail concerning the Gore Sorber survey, including the location of all sample points, is contained in the supplemental report submitted by Gore to Forest (W. L. Gore & Associates, Inc., 2000).

2.4.2 Processing Procedures

This section of the report is a summary of information contained in the report "Report of Findings, Gore-Sorber Exploration Survey, Caserta Block, Italy" submitted to Forest by W. L. Gore & Associates, Inc., dated March 14, 2000. Please refer to that report for a more detailed explanation. Sections of the report are quoted below.

"Various hydrocarbon compounds exist naturally in the soil gas environment even in areas without petroleum accumulations. The geochemical variations in soil gas data that distinguish subsurface sources of hydrocarbons from surface sources of hydrocarbons are often very subtle and hence difficult to identify visually. Therefore, data derived from the analysis of soil gas samples is processed statistically using such approaches as Hierarchical Cluster Analysis (HCA) and Discriminant Analysis (DA). For brief descriptions of these methods as applied to the study of soil gas data, refer to Appendix B [of the Gore report], 'The Gore-Sorber Exploration Survey Surface Geochemical Sampling System' ".

"The fundamental objective of Gore's geochemical data modeling and interpretation is to identify areas of hydrocarbon emanation, which indicate potential subsurface accumulations of petroleum (oil, condensate or gas). The geochemical modeling process usually includes defining the character of both petroliferous hydrocarbon and background soil gas signatures, using the Gore-Sorber Module at several 'known' locations or model well sites ('supervised' approach). Good producing wells which are in the same geological setting, have analogous production, and are not depleted and are near to original pressure conditions, are the best candidates for modeling petroliferous character. [There are no such wells nearby the Caserta Permit, although the Monte Taburno-1 well reported hydrocarbon shows (ed).]. Dry well sites at which absolutely no hydrocarbons were detected along the stratigraphic column are the best candidates for modeling geochemical background [The Morcone-1 well fits this description (ed).]."

"If no such 'known' model sites are available in the specific survey area, a process of geochemical data clustering is used to determine appropriate samples for modeling petroleum influence and/or geochemical background. A technique known as Hierarchical Cluster Analysis is used in this situation ('unsupervised' approach). In general, a modeling strategy based on 'known' subsurface presence or absence will yield better results than a purely 'unsupervised' approach, even with less than optimal model wells [The case at Caserta (ed).]."

"A 'semi-supervised' modeling approach was adopted for this project. Specifically, because there are no producing petroleum wells in or near the survey block, Forest selected a nearby gas show well (Monte Taburno-1, located about 10 kilometers east of the survey area) as a well most likely to yield a reasonable 'petroliferous' surface geochemical signature suitable for model development purposes. Forest also identified a reliable dry well site (Morcone-1) for defining 'background' surface geochemical character; the Morcone-1 well is located about 12 kilometers northeast of the Caserta Block..."

"Due to the uncertainty of the 'petroliferous' model site (Monte Taburno-1), hierarchical cluster analysis (HCA) was performed on the pre-qualified data set. HCA is a process that separates the data set into sample clusters or sets on the basis of geochemical similarities. Essentially, this procedure begins by splitting the samples into two groups (or tree branches) using gross differences in the geochemical make-up of the sample population. Each of these two branches is further divided based on the next most significant difference within the respective geochemical branch or cluster. Branching continues, each subsequent branch separation being based on more subtle differences than the preceding branch. Generally, a purely 'unsupervised' modeling approach involves selecting a specific geochemical cluster(s), based on the subjective evaluation of average geochemical signatures and cluster distribution, to represent 'petroliferous' and 'dry' geochemical character"

"The initial intent of this procedure was to determine how cluster analysis treated the model set samples. Following that analysis, subsequent decisions regarding a model development strategy were to be made."

"The fundamental assumptions of the modeling process are [were]:

- All model sets were collected from locations directly above the specific geochemical influence of interest (such as proven background or gas accumulation), and represent accurately and consistently the surface geochemical expression of that influence;

- The Morcone-1 dry well contains no hydrocarbons throughout the stratigraphic section; and

- Monte Taburno-1 contains gas hydrocarbon 'shows' ".

3. Integrated Structural/Stratigraphic Interpretation

3.1 Regional Geologic Discussion

The Caserta Permit lies some 30 kilometers north of Naples, just to the east of the volcanic trough that contains Mts. Vesuvius and Roccamonfina. It is well within the internal Apennine structural province, where the petroleum plays all involve the thrust relationships between the carbonate platforms of southern Italy, their intervening basins, and overlying Neogene flysch and piggyback basins. The general tectonic scheme of the Apennines is now well known: ophiolitic Ligurian nappes are thrust eastward over Triassic to Eocene platformal carbonates, which in turn are telescoped along with basinal time equivâlents of the platforms facies into thrust plates over an eastern autochthonous platform. The autochthonous platform (Apulia) outcrops in the Gargano Peninsula and Puglia (the 'boot heel' of Italy), but is involved at depth in the thrust system to the west. Various syn-orogenic flysch sequences of Miocene age are also involved in the eastward propagating system, as are piggyback and superimposed extensional basins. The Caserta Permit is located internally to the system, where the Apennine carbonate platform, Lagonegro-like basinal rocks, and the syn-orogenic flysch dominate outcrop, all thrust generally eastward over the westward-dipping Apulian platform.

A particularly important factor in Caserta is a strong Plio-Pleistocene overprint of extension that is chiefly related to the opening of the Tyrrhenian Sea and associated volcanism. The rim of the volcanic trough that contains Mount Roccamonfina crosses the southwestern part of the Caserta Permit, and numerous normal faults obscure the thrust architecture of the block. The Maggiore and Casertano ranges furnish outcrop of Apennine platformal rocks and their overlying flysch in the central and southern parts of the block, heavily overprinted by extensional deformation. The Volturno River valley transects the block from north to southeast, separating the Maggiore range from the Matese range, another area of platformal outcrop to the northeast of the Caserta Block. It then cuts west to separate the Maggiore range from Casertano and proceeds toward the Tyrrhenian Sea. The well Morcone-1 and its sidetrack lie just outside the block to the northeast. It is the only well in the area with direct application to the Caserta Permit. It was drilled on a surface anticline, but after cutting two faults it reached total depth in the steep limb of a southwestward-directed fault-propagation fold. It missed its target at depth, but it provides the best constraint on the thickness of several of the Mesozoic units in the block.

Obvious prospects are not evident from the surface geology. The primary targets for exploration are exposed, and breached in the ranges. Some seismic data have been collected in the block, but they are generally of poor quality. Lines BN-316-85-PX and BN-308-85-PX in particular suggest that the Volturno River lies in a structurally controlled valley, bounded on the northeast by southwestward directed thrusts of the Matese, and on the southwest (the Maggiore range front) by a normal fault system that cuts northeastward-directed thrusts. The surface geology clearly shows the Maggiore range-bounding normal fault system. As a result, exploration focus has been on the subsurface of the Volturno Valley.

The closest production to the Caserta Permit is the Benevento Field, about 40 kilometers to the east of the block. Benevento is typical of many southern Apennine fields in that production is from Mesozoic carbonates, underlying and sealed by Messinian flysch. The reservoirs are generally fracture-enhanced, and produce a variety of hydrocarbon grades. Benevento in particular produces 41° API oil from the Turonian at 3100 m.

3.2 Geologic Structural Cross-Sections

Two structure sections have been constructed to characterize the Caserta Permit. They are based on the following data:

1. The Caserta (Foglio 172) and Benevento (Foglio 173) 1:100,000 sheets of the Carta Geologica D'Italia produced in 1966 and 1970, respectively, by the Servizio Geologico D'Italia, reproduced in 1990 and 1992, respectively by the Instituto Poligrafico e Zecca dello Stato Roma.

2. The compilation logs for the Morcone 1 and 1-bis well.

3. Topography from AOA's DEM.

4. Seismic lines BN-316-85-PX and BN-308-85-PX.

5. AOA's gravity/magnetic/MT structural model profiles D, E, F, and G.

Section A-A' (Figure 15) ties the Morcone-1 well with the intersection of AOA profile E at the southern margin of the block. It cuts profiles F and G at a low angle, as well as seismic line BN-316-85-PX. The section shows several highs in the Cretaceous and Jurassic Apennine platform rocks within the Volturno Valley, partially set up by shortening in the Apennine thrust system but also amplified by rollover on the normal faults that form the geomorphic valley. Line B-B' (Figure 16) parallels AOA profile D, cutting seismic line BN-308-85-PX at a low angle. It shows a similar but larger structural high, cut by normal faults.

The geological sections must be taken as generalized. Previously published structure sections simply show simple Apennine thrust plates verging to the east overprinted by later Neogene extension. A certain amount of extra detail is possible at the scale of these sections, but they should be taken as generalized in nature. Both of the sections assume a detachment at about or deeper than 5.5 kilometers, and that the thrust geometries are overprinted by late Neogene extension. Allowances for complex syntectonic relationships between the flysch and the carbonates are not made, as evidence is scanty for a complex relationship on the geological maps available. The sections do, however, serve to justify exploration focus on the Volturno Valley, an area that has not yet been tested.

3.3 Discussion of Play Concepts

Source rocks for the Apennine internal fields are generally typed to upper Triassic and Liassic carbonate sequences with evaporitic affinities. Biogenic gas is generated from shallower units, but fields associated with this source are limited to the foredeep basin closer to the Adriatic Sea. Other young source rocks are possible, but none have been proven within the internal Apennine ranges. Reservoir is expected to occur in Mesozoic carbonates below a seal set up by Miocene flysch. Hence the best opportunity in Caserta would seem to be in the structures within the Volturno Valley, where both thrust-related structural features and extension rollover highs are sealed by flysch and situated in a good position to trap hydrocarbons generated deeper in the Triassic-Jurassic.

3.4 Discussion of the Integrated Interpretation

3.4.1 Volturno Trough - Possible Exploration Fairway

A potentially prospective sedimentary trend, marked by thick sequences of Tertiary clastics and flysch, is unambiguously indicated by the gravity and MT data. The trend is coincident in the northern and eastern portions of Caserta Block with the present-day Volturno River Valley. This sedimentary trend continues due south towards the southeastern block corner, its southerly axis passing near the town of S. Agata de Goti.

This fairway of thick calcareous sediments (primarily Miocene flysch, but including in the upper section thin tuffaceous deposits, sandstones, shales, and turbiditic deposits) attains maximum thickness just north of the Caserta Block, near the town of Alife. We designate this prominent sediment fairway as the Volturno Trough.

In Val D'Agri area (e.g., Monte Alpi Field), Cretaceous organic rich black shales, marls, and limestones have proven to be good source rocks (Albanesi, 1999; Holton, 1999a). Also worth pointing out is the fact that the Monte Taburno 1 well, located just east of Caserta Block, penetrated a Tertiary flysch sequence noted to be similar to, but different than, the Lagonegro (Albanesi, 1999). As will be discussed later, certain of the MT sounding sites indicate the presence of an intermediate resistivity calcareous sedimentary unit at depth within the Volturno Trough - electrically similar to an intermediate resistivity contact observed in the Val D'Agri that correlates to the Lagonegro basinal facies.

The Volturno Trough has a prominent gravity anomaly signature in corrected and processed gravity anomaly data. The location and approximate lateral extent of the trough are well delineated by a distinctive gravity anomaly minimum trend on the isostatic gravity anomaly map (Figure 10). The gravity anomaly minimum trend arises due to the presence of the lower density, valley-filling, clastics/flysch adjacent to and on top of much higher density Cretaceous Apennine Platform carbonate units (and in some places perhaps Apulian Platform carbonate units as well).

The regional gravity anomaly map (Figure 11) also provides an excellent first order depiction of the Volturno Trough. On this latter map, the regional gravity anomaly minimum trend in the northeast half of Caserta Block marks the location of the trough, whereas the flanking regional gravity anomaly maximum sweeping through the southwestern half of the block reflects massive, and commonly outcropping, Apennine limestones.

The gravity effect of the trough is also apparent on the Bouguer gravity anomaly map (Figure 6), but is less well resolved in the Bouguer anomaly data than in the isostatic gravity anomaly data - this because of the obscuring effect of the large Moho-related regional gravity gradient present in the Bouguer anomaly data. The Moho deepens northeastward beneath the project area - the crust thickening from the rifted Tyrrhenian Sea margin to the deep crustal roots of the Apennine Mountain chain that runs the length of the Italian peninsula.

Though no bulk density information is available for the sedimentary rocks in Caserta Block, wireline density logs (FDC) from the Agip Benevento Sud 1 well east of the block and the Agip Circello 1 well northeast of the block show Apulian Platform carbonate bulk densities on the order of 2.65 - 2.85 g/cc. Measured density values greater than 2.75 g/cc may well indicate dolomitic carbonate rocks. Apennine Platform carbonates are likely to be similar to Apulian Platform carbonates with regard to bulk density properties. Thus a considerable density contrast exists across the interface between buried Apennine limestone and overlying sequences of clastics/flysch and/or basinal carbonate facies. Quantitative structural traverse modeling performed during the project assumed a 0.25 g/cc density contrast between the Apennine carbonates and the overlying/adjacent flysch sequences.

The magnitude of the gravity anomaly minimum in the Volturno Trough affords a qualitative or rough indication of Tertiary clastic/flysch sediment thickness (or conversely, depth to Apennine carbonate). The potential for thicker hydrocarbon source rocks is thus inferred for the northeastern portion of the permit. This qualitative interpretation is borne out by the quantitative, integrated structural modeling results, discussed in the following two sections.

The residual gravity anomaly map and gravity vertical derivative maps (Figures 12 and 13 respectively) show finer scale features in the vicinity of the trough, most of which are investigated by the structural modeling described next.

3.4.2 Gravity/Magnetic/MT Structural Model Cross-Sections

Seven gravity/magnetic/MT structural model traverses, denoted A, B, C, D, E, F, and G, were constructed for the purpose of detecting and resolving the principal structural features (e.g., depressions, pop-up blocks, thrust-sheet imbricates, etc.) present in Caserta Block - with special emphasis given to the question of how such features relate to potential hydrocarbon charging from possible hydrocarbon source rocks in the Volturno Trough.

Locations of the seven model traverses are indicated on Figure 14, which is a 3-D gravity model result for the approximate depth-to-carbonate (based on inversion of the isostatic gravity anomaly). Structural model Line A is predominantly a strike line in terms of its structural orientation. The purpose of Line A is to (1) sample the Volturno Trough and (2) provide a line-tie between the structural dip lines B, C, D, E, F, and G.

The above mentioned 3-D gravity model result for the approximate depth-to-carbonate is the result of (1) assuming a 0.25 g/cc average density contrast between carbonates and overlying clastic/flysch units and (2) assuming that the bulk of the isostatic gravity anomaly can be attributed to the density contrast across the carbonate structural interface. The nature of the 3-D modeling algorithm is such as to prevent the modeling of overhang situations. Given these various assumptions and restrictions, the 3-D model result provided a reasonable starting point (initial model) for the detailed structural cross-section modeling of Lines A, B, C, D, E, F, and G.

Interpretive results from the MT sounding program were projected into the gravity and magnetic structural model depth-sections for those MT sites located reasonably close to the structural model line locations. The yellow square-shaped symbols on the model cross-sections denote resistive contacts detected by analysis of the MT measurements. These resistive contacts in most cases correspond to the boundary between the less resistive clastic/flysch sequence and the much more resistive Apennine Platform carbonate unit. However, in some cases, a shallower resistive contact can be resolved in addition to the Apennine platform contact - the shallower resistive contact is interpreted to correspond to the boundary between lower resistivity clastics/flysch and intermediate resistivity rocks of the basinal facies (possible Lagonegro equivalent).

The gravity and magnetic structural models include various fault traces based on surface geology information and the two structural cross-sections (Figures 15 and 16) completed by James Granath, the project structural geologist. The fault traces are included in the models merely to lend them a geological stylization appropriate to the Caserta Block. The point should be stressed that the fault plane surfaces are not detectable with either the gravity or magnetic data. Similarly, the inclusion of a regional horizontal detachment surface at 5.5 kilometers depth subsea in the models is based on structural geological considerations by James Granath. It should be noted, however, that the presence of this surface, at or close to the expected top of the Apula Platform carbonates, is strongly suggested by the MT results at several sites.

Lastly, Caserta Block ground magnetic data are also included in the structural models. However, use of these data proved highly problematic due to the considerable cultural noise present along the magnetic survey traverses, and also because the exposed and near-surface Quaternary pyroclastic flows and tuffs that occur over much of the survey area create extremely local (or short wavelength) magnetic anomalies that are inadequately sampled at the nominal 500-meter survey magnetic station spacing (i.e., the observed anomalies are aliased).

3.4.3 Structural Features of the Volturno Trough Area

Gravity/Magnetic/MT Line A

Structural model Line A (Figure 17) is predominantly a strike line in terms of its structural orientation. Line A is chosen to both (1) sample the Volturno Trough and (2) provide a line-tie between model dip lines B, C, D, E, F, and G. Line A, being a strike line, is poorly oriented for gravity structural modeling. Nonetheless, Line A serves to provide good general confirmation as to the reasonableness of the interpretations along the six modeled dip lines, B, C, D, E, F, and G.

Gravity/Magnetic/MT Line B

Structural model Line B (Figure 18) dramatically illustrates the Volturno Trough. The trough is interpreted as being filled with lower density clastic/flysch sequences down to a depth on the order of 5 kilometers subsea. The trough is 5-10 kilometers wide. The distinctive gravity anomaly minimum coincident with the Volturno Trough is indicative of the lower density clastic/flysch section. Analysis of

MT sounding site CA12 confirms the presence of a thick lower-resistivity (and lower-density) section overlying much more resistive (and dense) Apennine (or possibly too, Apulian) carbonate rocks - consistent with the gravity interpretation. Note too that an intermediate higher resistivity contact is also detected at MT site CA12. This contact possibly corresponds to the basinal carbonate facies (Lagonegro equivalent).

Outcropping Apennine carbonates on the southwestern portion of the line (western portion of the permit area) are shown by gravity and MT modeling as being decidedly massive in nature (possibly multiple Apennine thrust sheets), with little possibility for significant overthrust clastic/flysch sequences. The possibility of a thin overthrust clastic/flysch section is suggested by gravity modeling beneath MT site CA19.

Southwest of MT site CA20, gravity modeling reveals westward deepening carbonates beneath the Campanian Plain. The Campanian Plain is an extensive down-faulted area (extensional graben zone) situated just to the southwest of the permit area, but which includes the area around the city of Caserta.

Survey magnetic data, though difficult to interpret due to cultural noise and data sampling limitations, indicate probable igneous intrusives (dikes/plugs and possible sills) - these appear to possibly be the extension of an igneous feeder system radiating away from the large Roccamonfina volcanic complex due west of the block.

The observed magnetic field gives no clear indication of structural or compositional changes within igneous basement, possibly because the observed magnetic traverse is rather short compared with expected basement depths. Igneous basement in the model is set at a depth of 10 kilometers subsea. No local information is available on average basement depth in the study area - though it is widely accepted as being quite deep.

From the point of view of block prospectivity, structural model Line B is important in that it confirms and gives a sense of scale for the clastic/flysch sequences filling the Volturno Trough.

Gravity/Magnetic Line C

Structural model Line C (Figure 19) is similar to Line B in illustrating the Volturno Trough, the massive (possibly stacked) Apennine limestones southwest of the Volturno Trough, and the westward deepening carbonate surface beneath the Campanian Plain.

Line C also shows the development of northeast vergent thrusting, with a thin Apennine plate thrust over a presumed clastic/flysch sequence. However, the subthrust clastic/flysch sediments are not particularly voluminous or thick (e.g., on the order of 1 kilometer).

The most notable exploration feature on Line C is the positive structure (higher density and higher resistivity, interpreted as Mesozoic carbonates) that arises from the floor of the Volturno Trough. This positive structure is seen to be part of an arcuate, northeast-directed structural "salient", which shows up quite clearly on the residual gravity anomaly map (Figure 12). The buried salient is interesting in that it occurs in a portion of the Volturno Trough with considerably thick surrounding flysch and presumed basinal carbonate facies material. Though it is of narrow width, its curvilinear length increases its prospectivity. Such structural salients, due to their special geometries, can be particularly prospective as they can act as foci for hydrocarbon migration (Macedo and Marshak, 1999).

Due to the lack of magnetic stations directly along Line C, the observed magnetic field is interpolated from magnetic readings made off of the line. Thus it is sensible to limit any modeling of the interpolated magnetic field along line C to fitting the regional trend only in the magnetic field. A more highly magnetized zone is included within the basement in order to fit the northeastward increasing regional tilt in the magnetic field. This more magnetic basement zone is also supported by magnetic modeling of Lines D, E, F, and G to the east.

None of the MT sounding sites are close enough to justify their projection into the Line C model depth-section. The location of Line C was chosen strictly because it optimally samples the aforementioned structural salient buried within the Volturno Trough. While the location of Line C is optimum for this purpose, analysis of the salient would be aided by additional gravity and MT data.

Gravity/Magnetic/MT Line D

The Volturno Trough is well traversed by structural model Line D (Figure 20), with the overlying clastic/flysch sequence and presumed basinal carbonate facies still being quite thick - on the order of 2,500 meters or so. The intermediate resistivity contact detected at MT sites CA01 and CA14 is intriguing as it is possibly related to the basinal carbonate facies (Lagonegro equivalent).

Once again, gravity and MT analysis shows the outcropping Apennine section on the southwestern portion of the line to be very massive, with only a thin veneer of clastics/flysch or overthrust clastics/flysch sequences.

Of exploration note is the interesting Mesozoic pop-up block that occurs between MT sites CA17 and CA15. The block forms a faulted, structural closure which would appear to offer some interesting hydrocarbon trapping possibilities.

Line D shows the development of a northeast vergent Apennine thrust plate over a presumed clastic/flysch sequence. The overthrust is supported by both the gravity and the MT interpretation (MT site CA17). However, the subthrust clastic/flysch sediments are not particularly voluminous or thick (e.g., less than 1 kilometer).

The westward deepening carbonate surface beneath the Campanian Plain is again seen on Line D (southwest line end).

With respect to the behavior of the observed magnetic field along Line D, a northeastward increasing regional "arch" in the field is fit by elevating basement along the central portion of the line and by increasing the magnetization of the central basement zone. The local (or short wavelength) magnetic anomalies observed on Line D correlate directly to Quaternary surface or near-surface pyroclastic flows and tuffs (e.g., ignimbrites).

Gravity/Magnetic/MT Line E

Modeled profile E (Figure 21) is intriguing in that the gravity analysis reveals a southwest vergent Apennine thrust on the northeastern line end. Thickness of the overthrust clastic/flysch package is interpreted to be on the order of 1,500 meters. In addition, additional positive structures (Apennine, or possibly Apulian, limestones and dolomites) rise from the floor of the Volturno Trough. A decrease in thickness of the Tertiary clastic/flysch package filling the Volturno Trough occurs in moving south along the eastern corridor of Caserta Block. This sedimentary thinning within the trough can be seen on Line E, in particular if it is compared with Lines B, C, and D.

Outcropping Apennine limestone that occurs near the southwestern line end is seen to be generally thick and massive, just as in the case of the Apennine outcrops traversed by Lines B, C, and D.

The westward deepening carbonate surface beneath the Campanian Plain is again seen on Line E (southwest line end).

Similar to Line C, a northeastward increasing regional "arch" in the magnetic field is fit by elevating basement along the central portion of the line and by increasing the magnetization of the central basement zone. The local (or short wavelength) magnetic anomalies correlate rather definitively to Quaternary surface or near-surface pyroclastic flows and tuffs (e.g., ignimbrites).

Evidence for the interpreted southwest directed thrusts that occur within the Apennine floor of the Volturno Trough comes from seismic line BN-316-85. An interesting question is whether the modeled basement uplift along the central portion of the line is responsible for the southwest vergent Apennic thrust located at the northeast line end.

<u>Gravity/Magnetic/MT Line F</u>

Line F (Figure 22) shows numerous positive Apennine structures within the Volturno Trough. As in the case of Line E, a southwest vergent Apennine plate at the northeastern line end is thrust over a clastic/flysch sequence, the latter modeled as being 1,250 meters or so thick. Evidence for the interpreted southwest directed thrusts that occur within the Apennine (or Apulian) floor of the Volturno Trough comes from seismic line BN-316-85.

Outcropping Apennine limestone at the southwest line end is seen to be part of a long sheet of overthrust carbonate, which appears to be part of the same sheet modeled on Line E, and on Line G (to be discussed next).

Line F, together with Line G, offers some of the strongest evidence for structural variations in the underlying igneous basement. The regional trend in the observed magnetic anomaly field can best be fit by a combination of basement structural relief and an increase in basement magnetization over the central and northeastern portions of the line. The local (or short wavelength) magnetic anomalies correlate well with Quaternary surface and near-surface pyroclastic flows and tuffs (e.g., ignimbrites). The curious opposing sense of vergence of Apennic thrusts on either side of the modeled basement high suggests possible basement control on thrusting - a possibility also suggested by Line E.

Gravity/Magnetic/MT Line G

Structural model Line G (Figure 23) bears a resemblance to Line F in terms of the structural features that it traverses. A southwest vergent Apennine sheet is thrust over clastic/flysch units at the northeastern line end. This thrusted sheet-complex seems related to those interpreted on Lines E and F. Note how the low density clastic/flysch section filling the Volturno Trough has thinned from a maximum interpreted thickness of 5 kilometers or so on Line B to roughly 2 kilometers maximum thickness on Line G.

Evidence for the interpreted southwest directed thrusts that occur within the Apennine floor of the trough comes from seismic line BN-316-85. This seismic line also corroborates the southwestward deepening trend in the Apennine surface.

The same northeast vergent Apennine thrust sheet noted earlier at the southwestern ends of Lines E and F is seen on Line G to also be thrust over a clastic/flysch sequence, in this case a kilometer or so thick.

Line G, together with Line F, offers some of the strongest evidence for structural variations in the underlying igneous basement. The regional trend in the observed magnetic anomaly field can best be fit by a combination of basement structural relief and an increase in basement magnetization over the central and northern portions of the line. The local (or short wavelength) magnetic anomalies correlate rather definitively to Quaternary surface or near-surface pyroclastic flows and tuffs (e.g., ignimbrites). The curious opposing sense of vergence of Apennic thrusts on either side of the central basement high suggests possible basement control on thrusting - a possibility also suggested by the interpretation results for Lines E and F.

3.4.4 Discussion of the Geochemical Results

This section of the report is at least partially a summary of information contained in the report "Report of Findings, Gore-Sorber Exploration Survey, Caserta Block, Italy" submitted to forest by W. L. Gore &

Associates, Inc., dated March 14, 2000. Please refer to that report for a more detailed explanation. Sections of the report are quoted below.

Two geochemical models were developed based on the results at the 'petroliferous' well (Monte Taburno-1) and the 'dry' well (Morcone-1). "Each geochemical model was compared to the samplers deployed throughout the survey area (grid samples, or 'unknowns') and values were derived which quantify the similarity between the survey sample and the model. The result of this comparison is expressed as a probability value, from 0% to 100%, of being like the 'petroliferous' signature (as defined by the geochemistry of the samples from Monte Taburno-1..."

"The derived probability values are presented as color contour maps on Plates 1 and 2 [of the Gore report]. These maps illustrate computer-generated contour surfaces of probability values calculated for each sample location..."

The results of the analysis indicate that, "several moderate size geochemical features are defined in the northwest, northeast, southeast and southwest portions of the Caserta Block"... ..."The central portion of the block is generally devoid of any anomalous features."

While the geochemical sampling is limited in areal extent, an interesting observation can be made in the northwestern portion of Caserta Block (refer to Figure 24). Low probability petroliferous signatures are present over the outcropping and thrusted Apennine carbonates of the Mt. Maggiore unit - consistent with the unit's interpretation from gravity and MT data as being comprised of massive, probably stacked, Apennine carbonate thrust sheets. Interestingly, a high probability petroliferous signature occurs in the Volturno Valley along the outcropping northeastern leading edge of the thrusted Mt. Maggiore unit - strongly suggestive of hydrocarbon seepage on the margin of the Volturno Trough. These observations imply that the possible surface seepage is apparently facilitated in the valley by the lack of an overlying barrier of massive Apennine carbonates - just the observation one should not be surprised to expect provided a hydrocarbon source is present in the Volturno Trough.

The anomalous areas, areas with a geochemical signature most like that of the Monte Taburno-1 well, in general form a pattern roughly coincident with the Volturno Trough. This correlation implies the presence of a subsurface hydrocarbon suite similar to that present at Monte Taburno-1. While the ultimate significance of this correlation remains to be tested, the geochemical results certainly do not detract from the exploration potential of the feature, and in fact may support the hypothesis of prospective reservoirs in the area.

4. Conclusions on Prospectivity

A potentially prospective sedimentary trend, marked by thick sequences of Tertiary clastics and flysch, is unambiguously indicated by gravity and MT data. The trend is coincident in the northern and eastern portions of Caserta Block with the present-day Volturno River Valley. This sedimentary trend continues due south towards the southeastern block corner, its southerly axis passing near the town of S. Agata de Goti. This fairway of thick calcareous sediments attains maximum thickness just north of the Caserta Block, near the town of Alife.

Numerous buried Mesozoic carbonate structures are interpreted to occur at the "basinal floor" of the valley, including for instance the arcuate salient on Profile C, the pop-up structure on Profile D and GRANATH Section B-B', and the numerous structures, some overthrust, on Profiles E, F, G, and GRANATH Section A-A'. These structures may be Apennine and/or Apulian. The latter possibility, if true, would prompt the question of why the Apennine is absent within the valley.

Hydrocarbon source rocks for the Apennine internal fields are generally typed to upper Triassic and Liassic carbonate sequences with evaporitic affinities. Biogenic gas is generated from shallower units, but fields associated with this source are limited to the foredeep basin closer to the Adriatic Sea. Other young source rocks are possible, but none have been proven within the internal Apennine ranges. Reservoir is expected to occur in Mesozoic carbonates below a seal set up by Miocene flysch.

By analogy with the prospective Val D'Agri area to the southeast, several conditions thus appear to exist that make the Volturno Trough a prospective exploration fairway. The best exploration opportunities in Caserta Block would seem to be the structures within the Volturno Valley, where both thrust-related structural features and extension-related rollover highs are sealed by flysch and situated in a good position to trap hydrocarbons generated from within the Triassic-Jurassic section.

Hydrocarbon source is presumably the standard Triassic-Jurassic source that is common to all of the southern Apennine oil fields, though a hydrocarbon source could also be deeper from within the Apulian platform itself. There is also evidence to the north that an Eocene source exists but it is not known what facies this is in (i.e., in the platform section or the intervening basinal section). Good quality reservoirs are likely to occur in structures comprised of Apennine and/or Apulian carbonate platform rocks. Structures within the Volturno Trough would appear to be well sealed by overlying and draping sequences of flysch and post-orogenic valley sediments. In addition, MT data indicate that equivalents of the Lagonegro are also likely to be involved as part of the general sealing section.

5. References

Albanesi, L., 1999, Personal communication.

AOA Geophysics Inc., and Geoinvest SRL, 2000, Operations report - gravity, magnetic, magnetotelluric and surface geochemical surveys - Caserta Permit - Campania, Italy: Proprietary Gravity and Magnetic Survey Operations Report for Forest Oil International.

Cavinato, G. P., and De Celles, P. G., 1999, Extensional basins in the tectonically bimodal central Apennines fold-thrust belt, Italy: Response to corner flow above a subducting slab in retrograde motion: Geology, v.27, 955-958.

Endignoux, L., Moretti, I., and Roure, F., 1989, Forward modeling of the southern Apennines: Tectonics, v.8, 1095-1104.

Geoinvest SRL, 1999, Caserta Permit -1999 - gravity and magnetic survey principal facts: Proprietary Gravity and Magnetic Survey for Forest Oil International.

Geological Society of Italy, 1988, Geological map of southern Apennines: 74th Congress of the Geological Society of Italy.

Holton, J., 1999a, S. Apennines success bodes well for potential off southern Italy - Part 1: Oil & Gas Journal, v.97 (Nov. 29), 65-68.

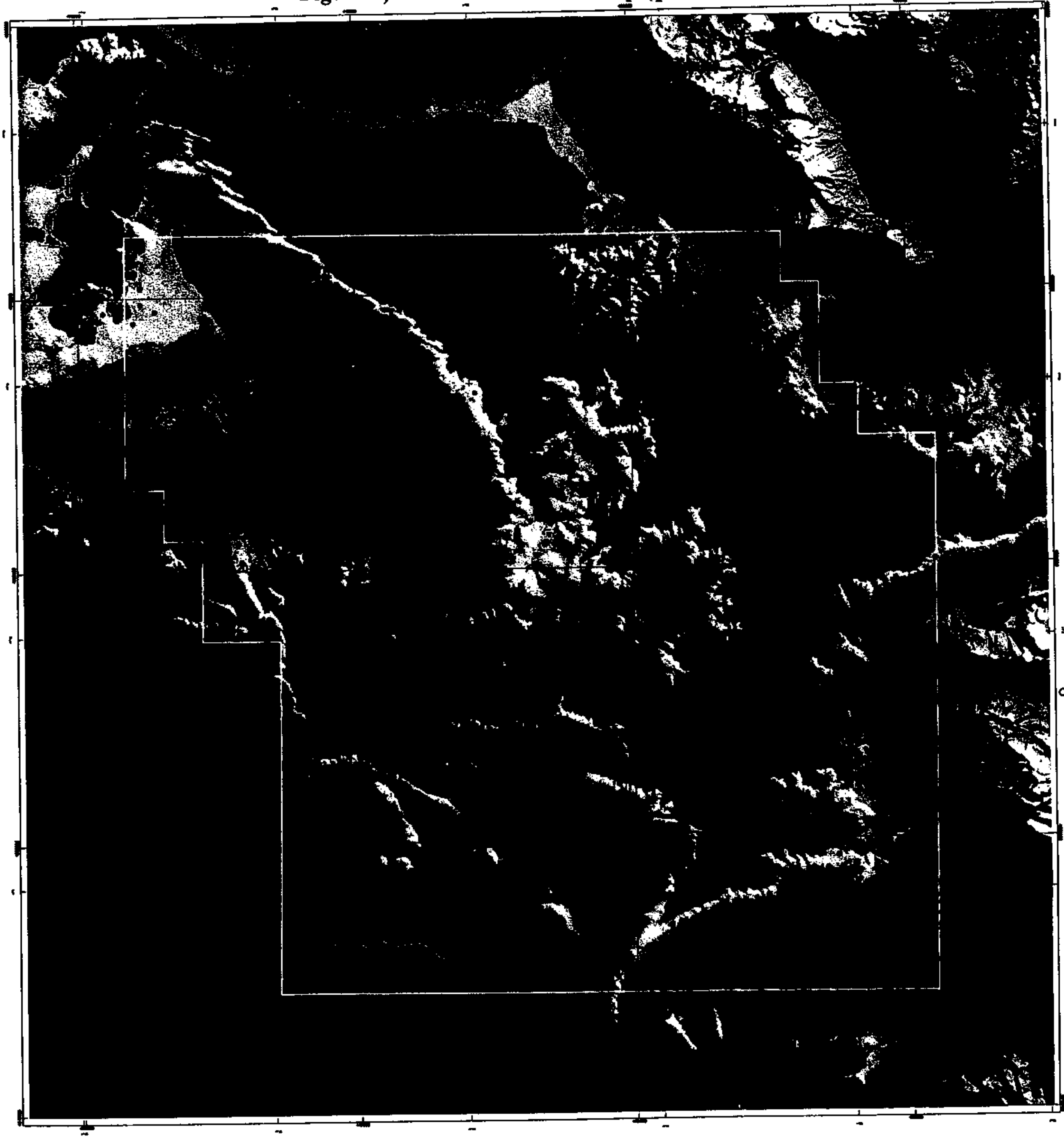
Holton, J., 1999b, Four geologic settings dominate oil, gas fields of Italy, Sicily - Part 2: Oil & Gas Journal, v.97 (Dec. 6), 81-84.

Macedo, J., and Marshak, S., 1999, Controls on the geometry of fold-thrust belt salients: GSA Bulletin, v.111, 1808-1822.

Pawlowski, R., 2000, GIS applied to exploration: Caserta Block, Central Apennines, southern Italy: The Leading Edge, v.19, 193-196.

W. L. Gore & Associates, Inc., 2000, Report of findings, Gore-Sorber exploration survey, Caserta Block, Italy: Proprietary Geochemical Survey Report for Forest Oil International.

Figure 1) Terrain Elevation Map (meters a.s.l.)



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MAP SYMBOL LEGEND

- Gravity Station - 1999 Field Program
- Gravity Station - NIMA Open File Data
- Magnetic Station - 1999 Field Program
- Mag Base Station - 1999 Field Program
- MT Site - 1999 Field Program

Terrain Elevation (meters a.s.l.)
IGM 20-meter DEM & USGS 30-sec GTOPO30

FOREST OIL INTERNATIONAL

CASERTA BLOCK

Central Apennines - Southern Italy

TERRAIN ELEVATION (meters a.s.l.)

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Houston, Texas 77042 USA

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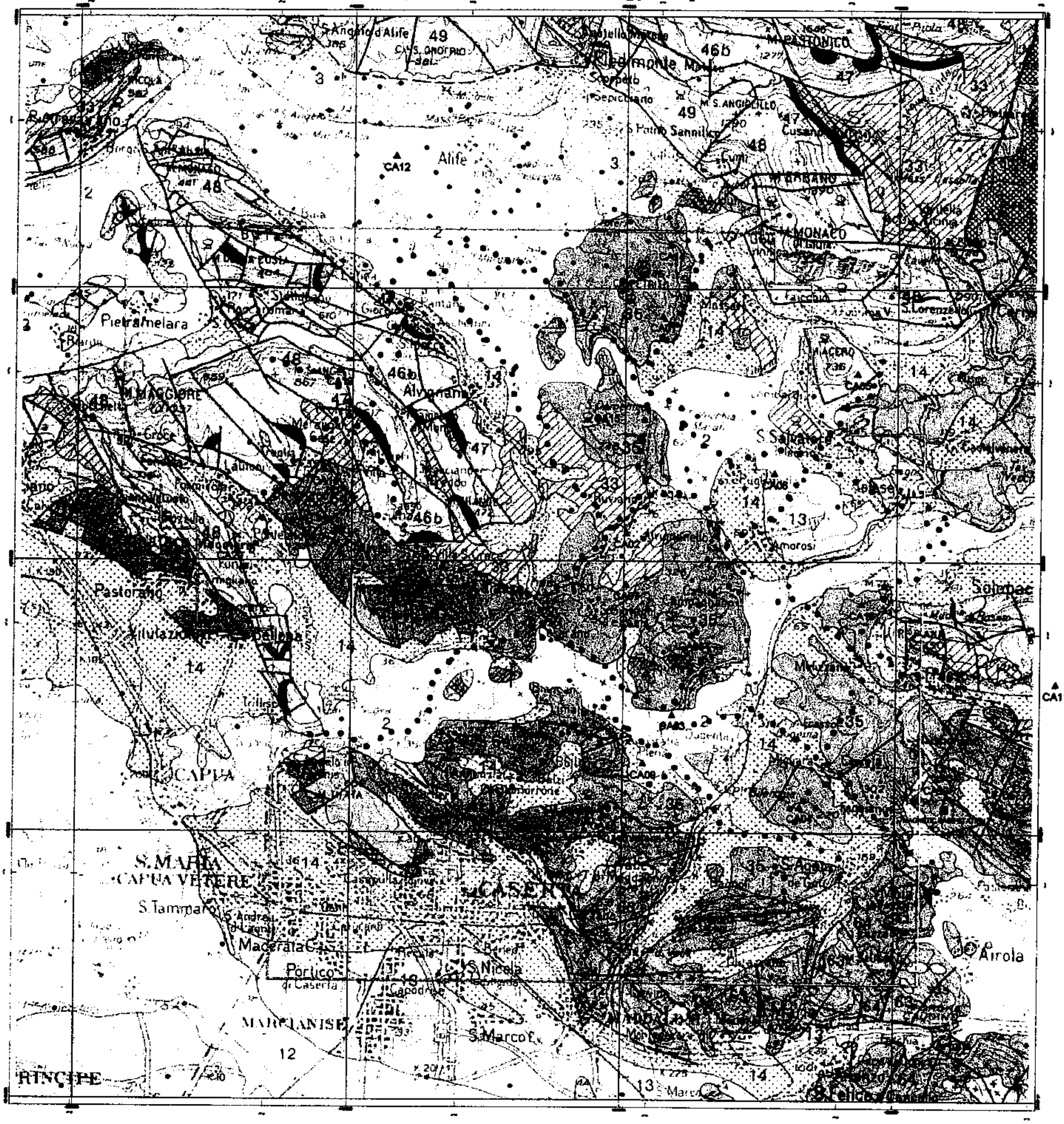
Robert Pawlowski - 05/2000

Figure 2) Surface Geology Map



MAP SYMBOL LEGEND

- ● Gravity Station - 1999 Field Program
- • Gravity Station - NIMA Open File Data
- · Magnetic Station - 1999 Field Program
- ■ Mag Base Station - 1999 Field Program
- ▲ MT Site - 1999 Field Program

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CASERTA BLOCK

Central Apennines - Southern Italy

SURFACE GEOLOGY WITH TERRAIN SHADING

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Robert Pawlowski - 06/2000

Figure 3) LANDSAT TM Image (321) Map

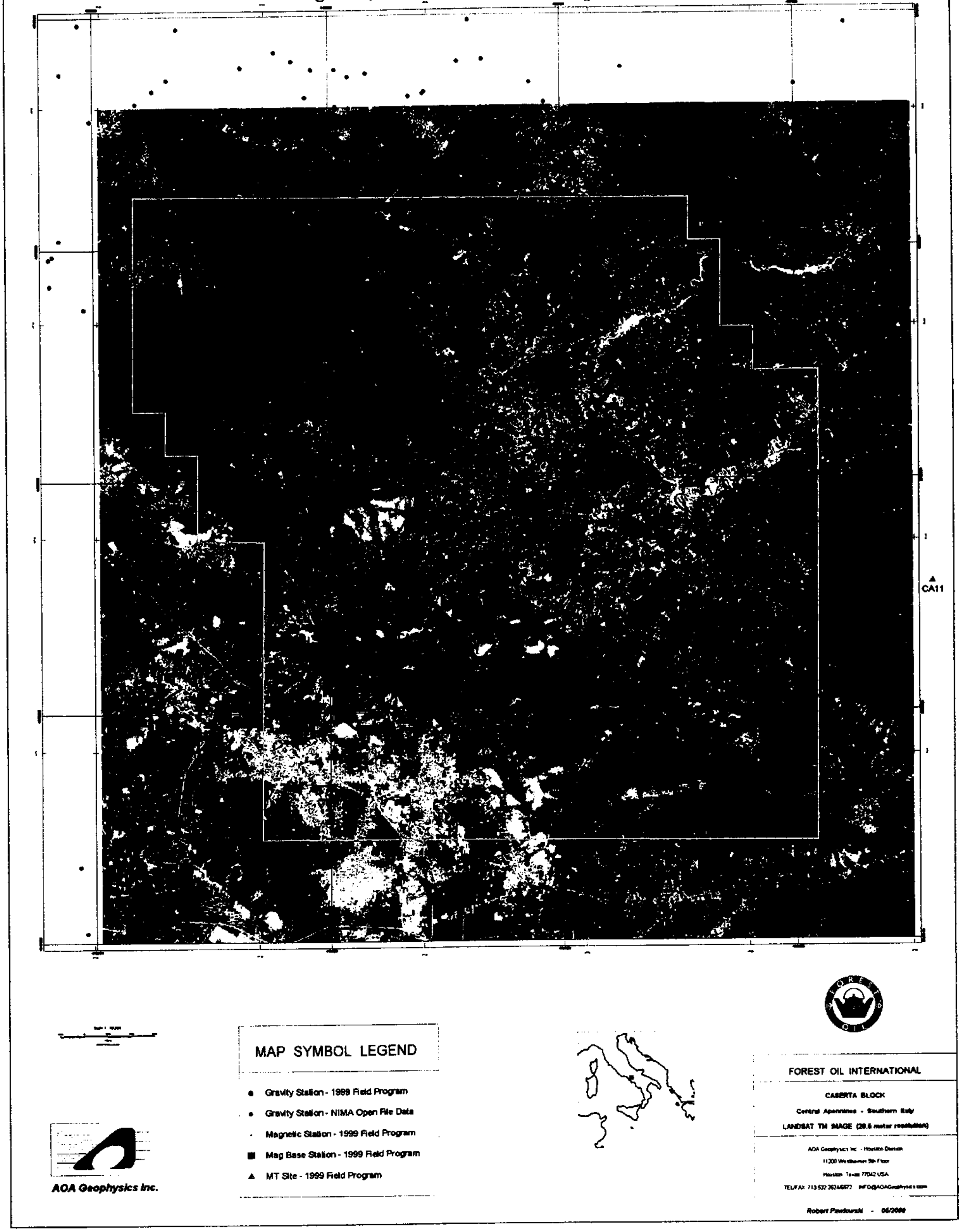
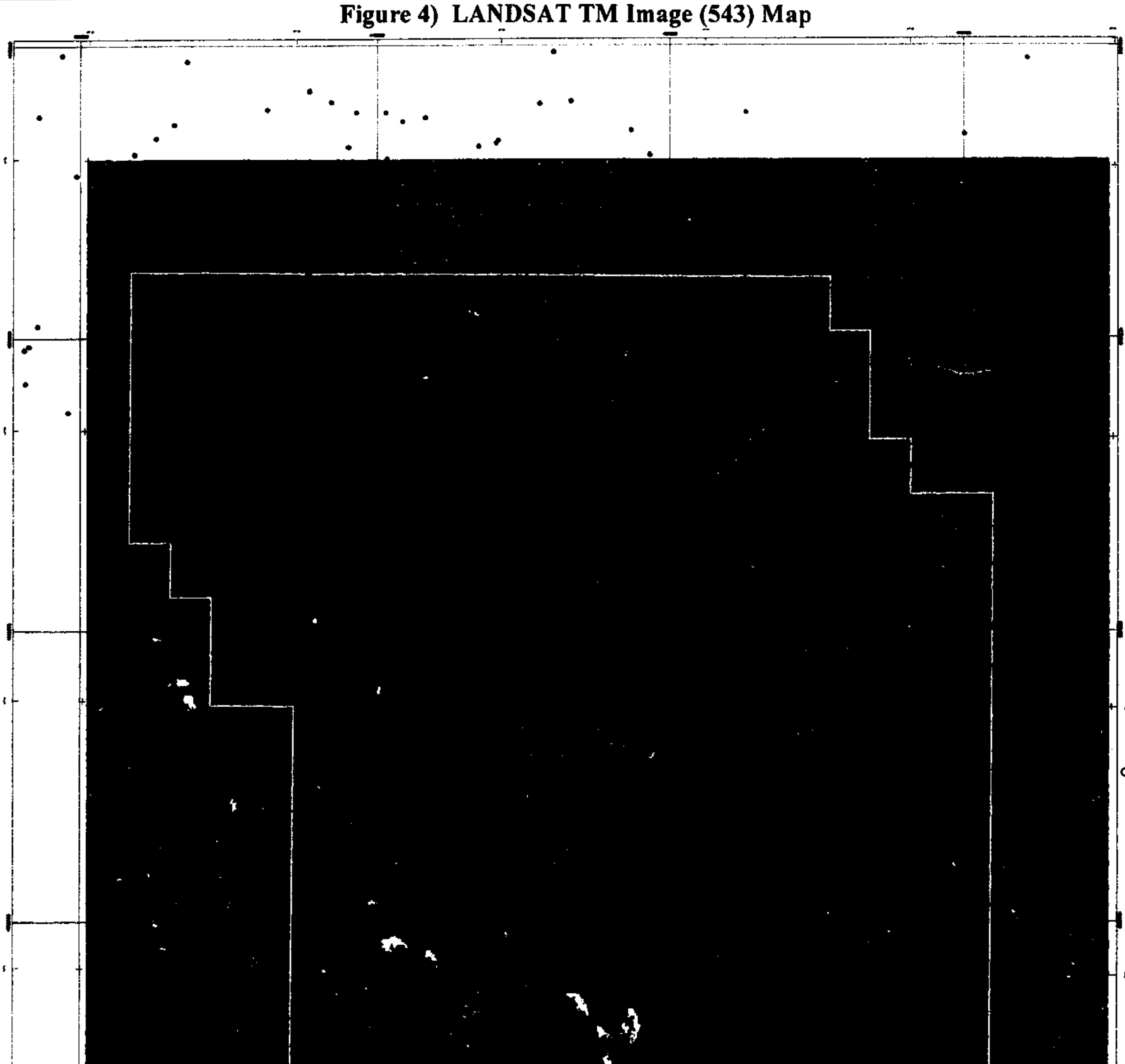


Figure 4) LANDSAT TM Image (543) Map



MAP SYMBOL LEGEND

- Gravity Station - 1999 Field Program
- Gravity Station - NIMA Open File Data
- Magnetic Station - 1999 Field Program
- Mag Base Station - 1999 Field Program
- MT Site - 1999 Field Program

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CASERTA BLOCK

Central Apennines - Southern Italy

LANDSAT TM IMAGE (28.5 meter resolution)

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Figure 5) Free-Air Gravity Anomaly Map (mGal)

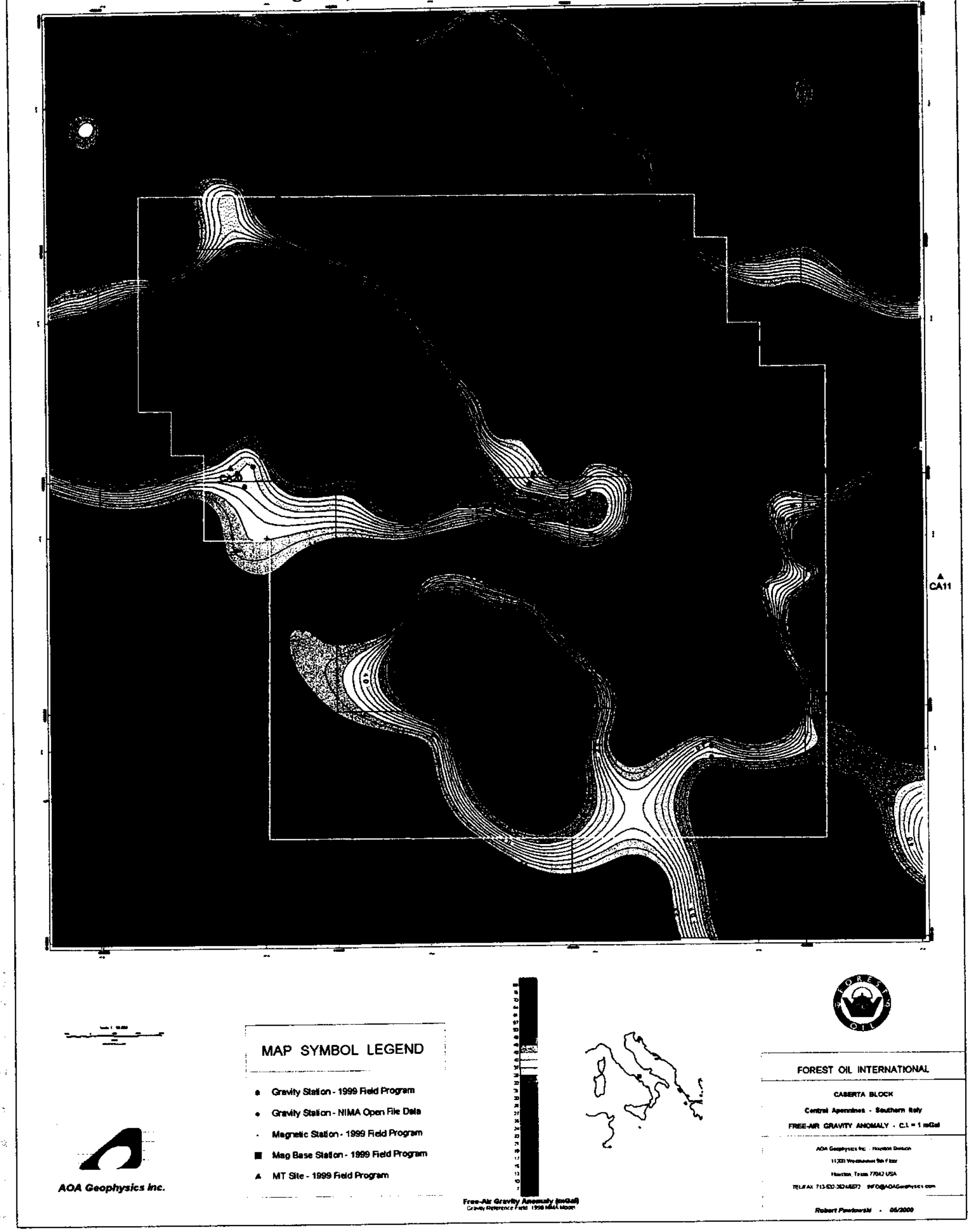


Figure 6) Bouguer Gravity Anomaly (2.63 g/cc) Map (mGal)

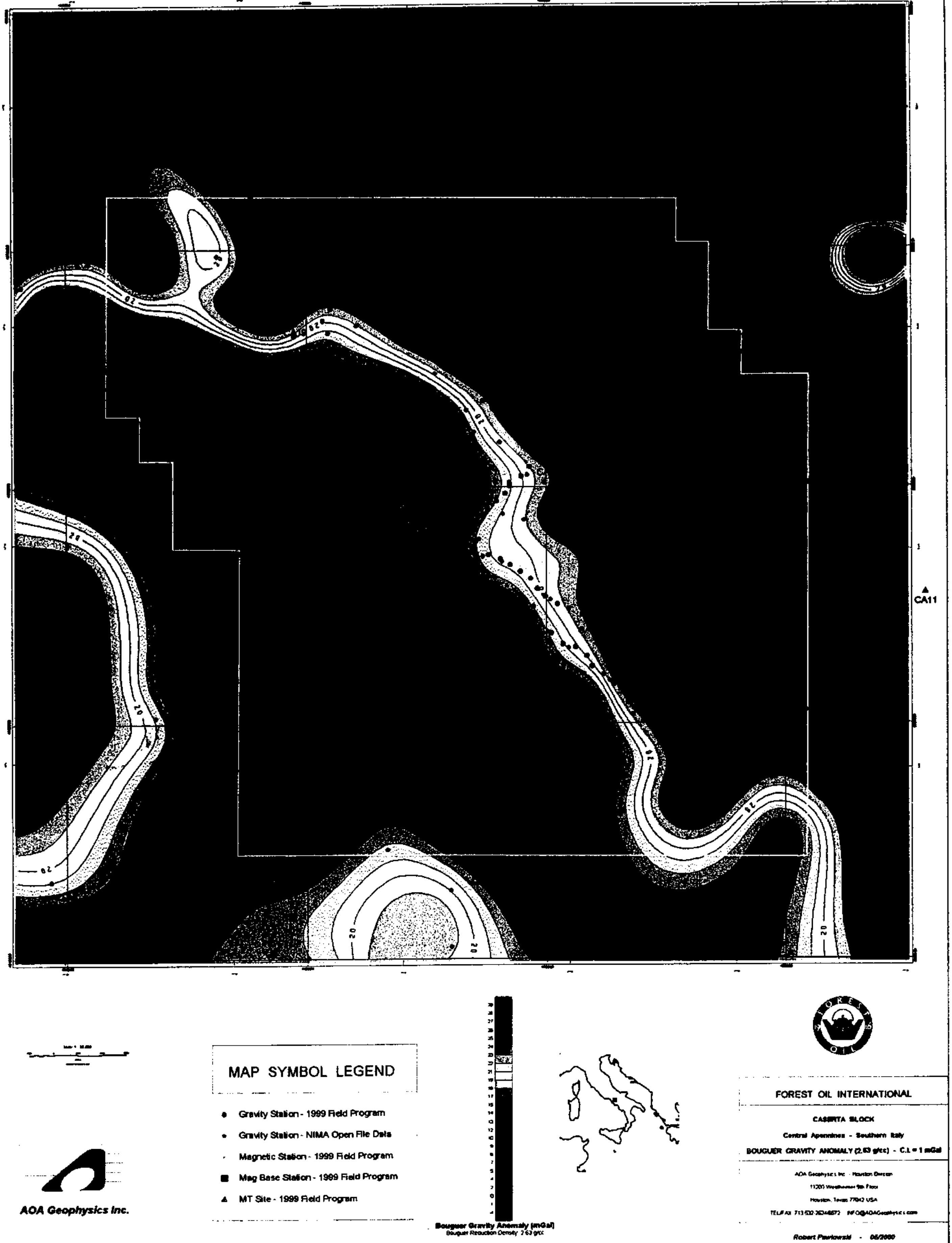
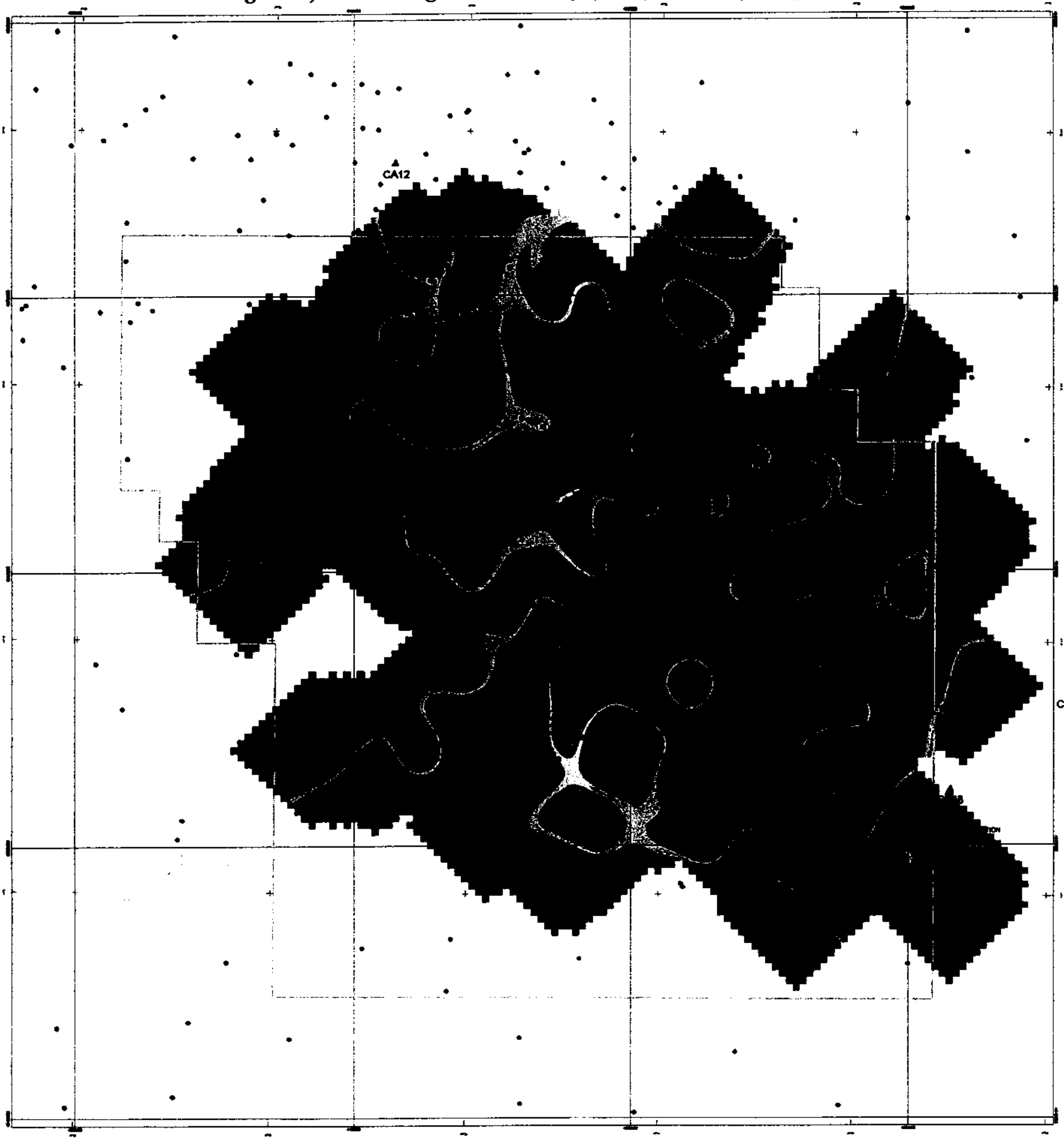


Figure 7) Total Magnetic Intensity (TMI) Anomaly Map (nT)



MAP SYMBOL LEGEND

- ● Gravity Station - 1999 Field Program
- • Gravity Station - NIMA Open File Data
- · Magnetic Station - 1999 Field Program
- ■ Mag Base Station - 1999 Field Program
- ▲ MT Site - 1999 Field Program

TMI Magnetic Anomaly (nT)
Total Magnetic Intensity (TMI)

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CASERTA BLOCK

Central Apennines - Southern Italy

TMI MAGNETIC ANOMALY - C.I. = 5 nT

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Figure 8) Reduced-to-Pole (RTP) Magnetic Anomaly Map (nT)

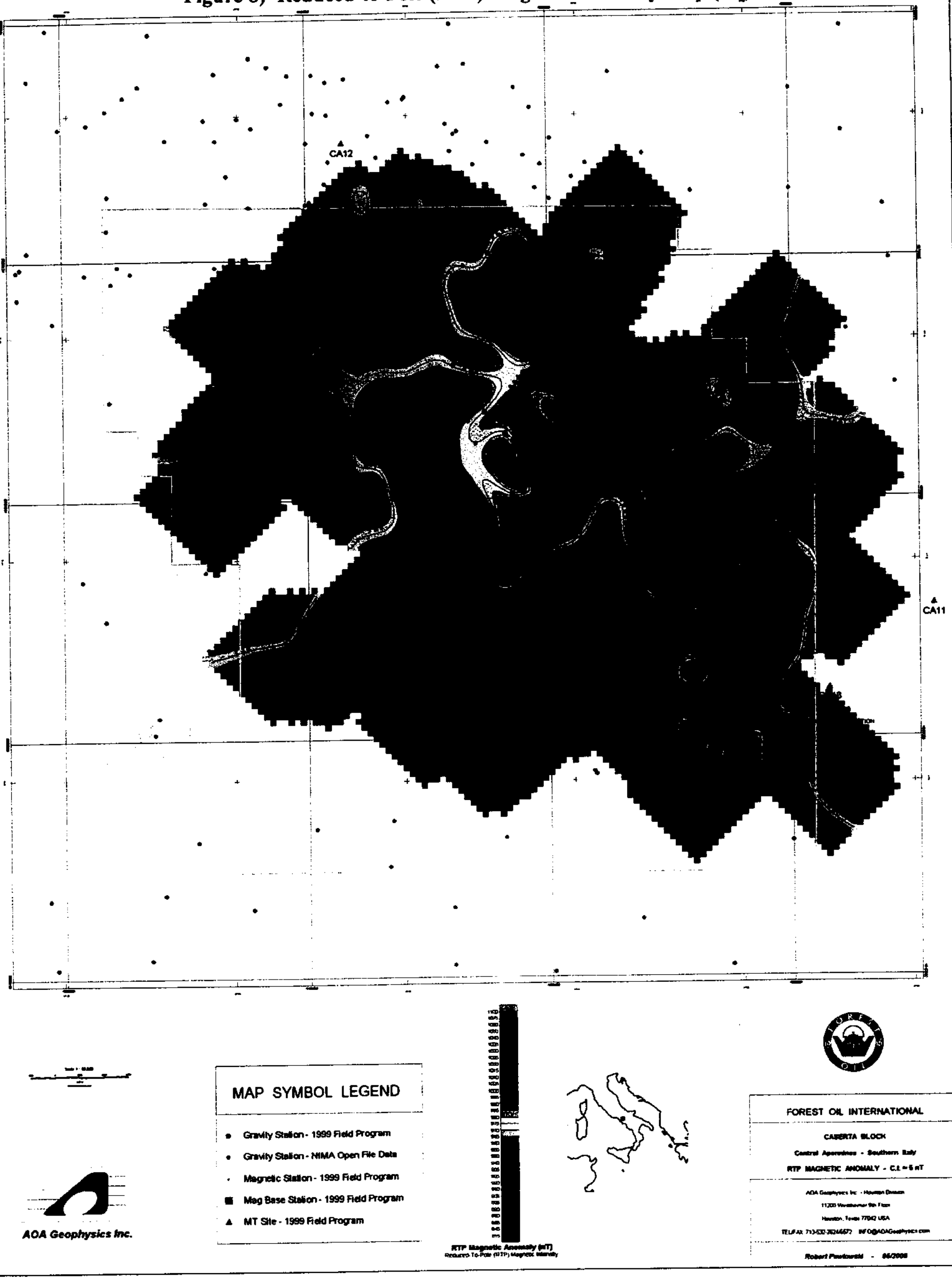


Figure 9) Second Vertical Derivative of RTP Magnetic Anomaly Map (nT/m/m)

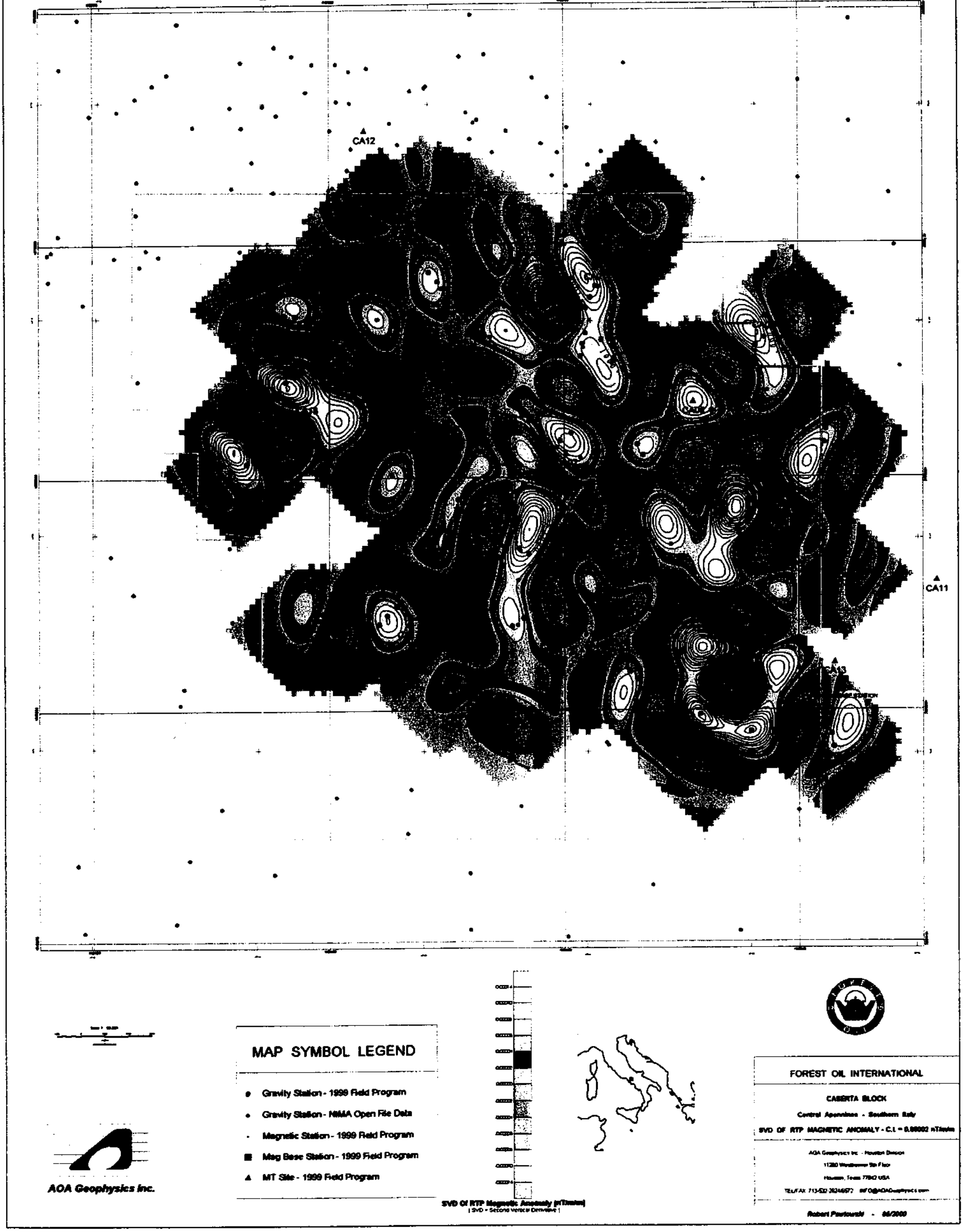


Figure 10) Isostatic Gravity Anomaly Map (mGal)

Figure 11) Regional Gravity Anomaly Map (mGal)

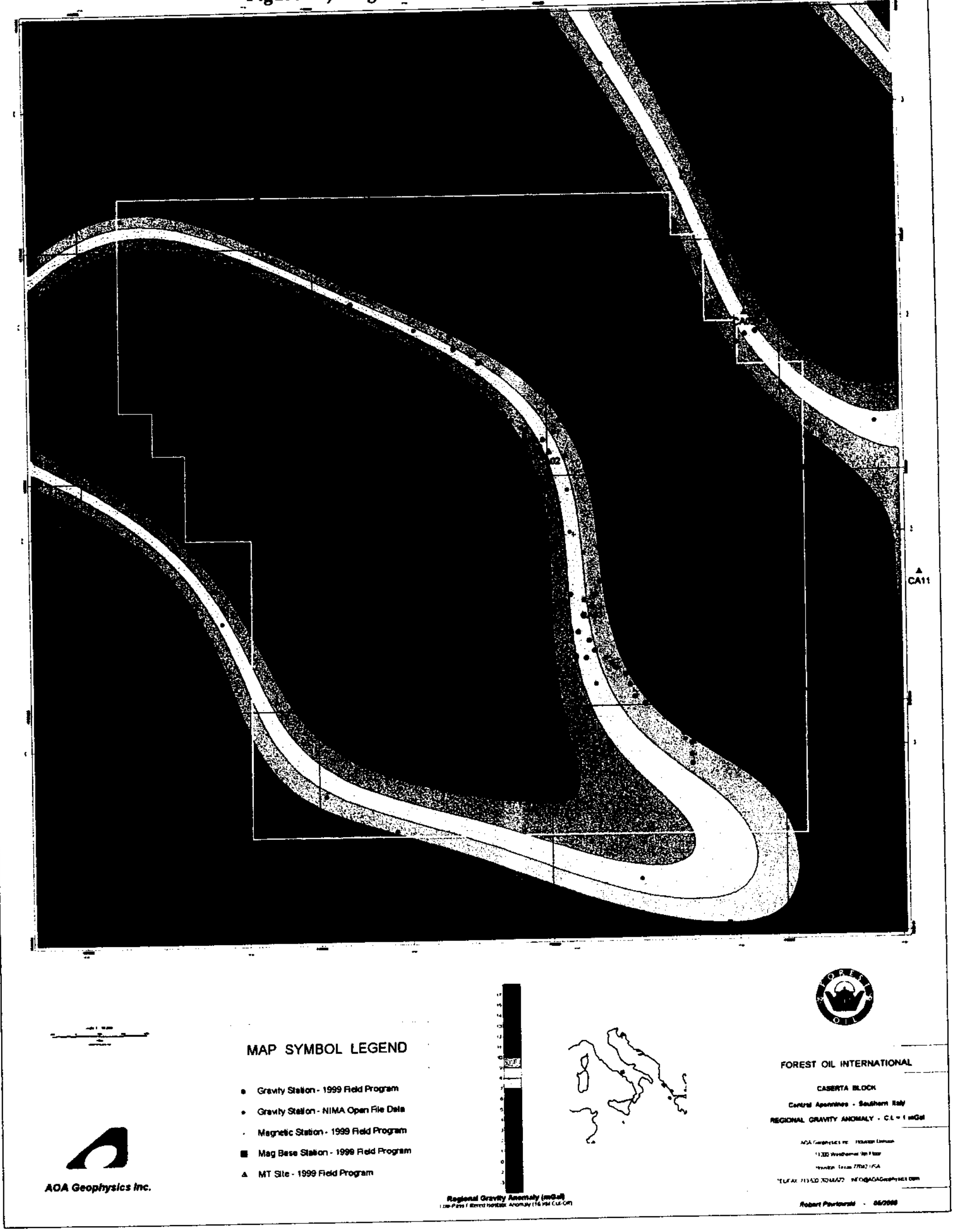


Figure 12) Residual Gravity Anomaly Map (mGal)

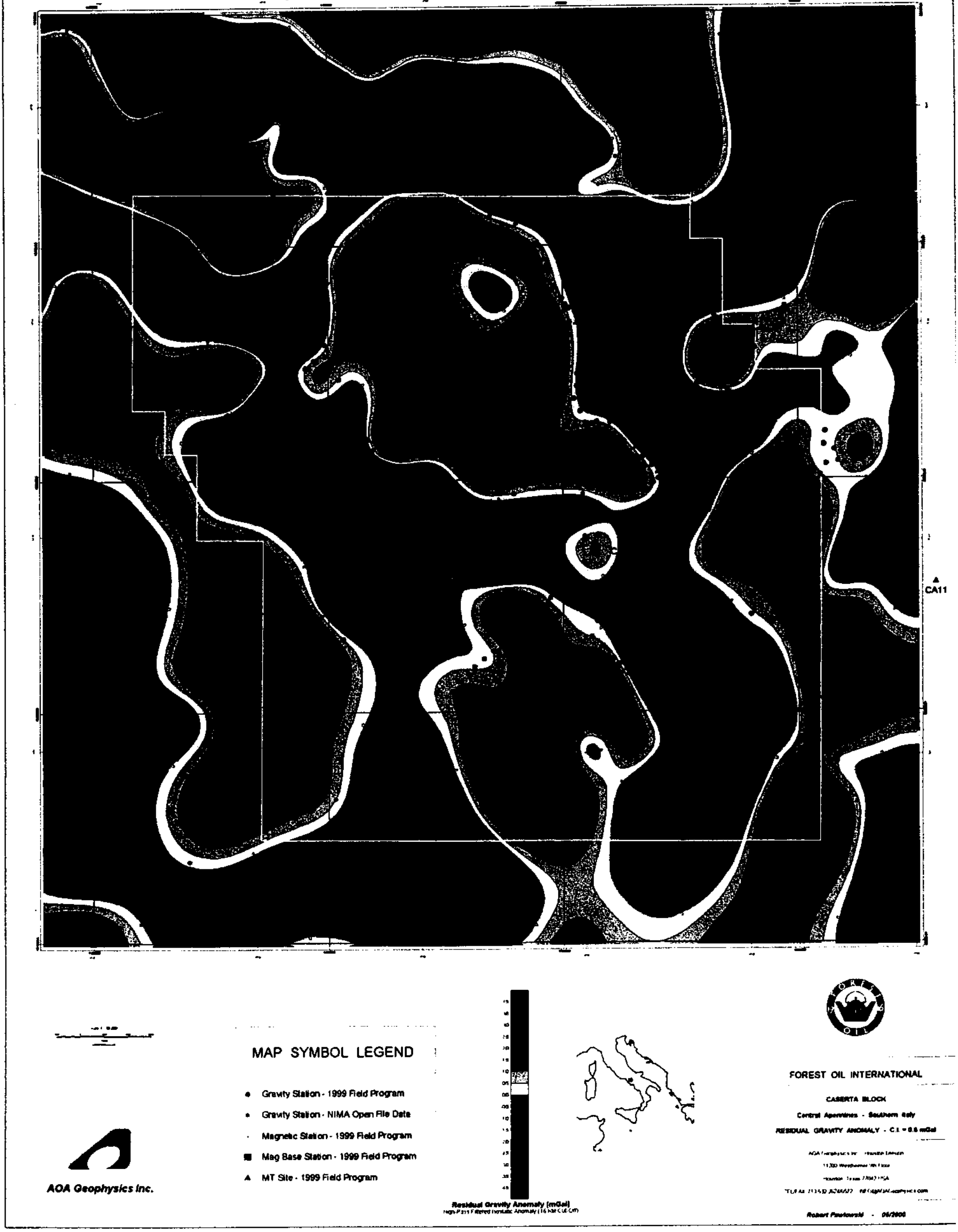
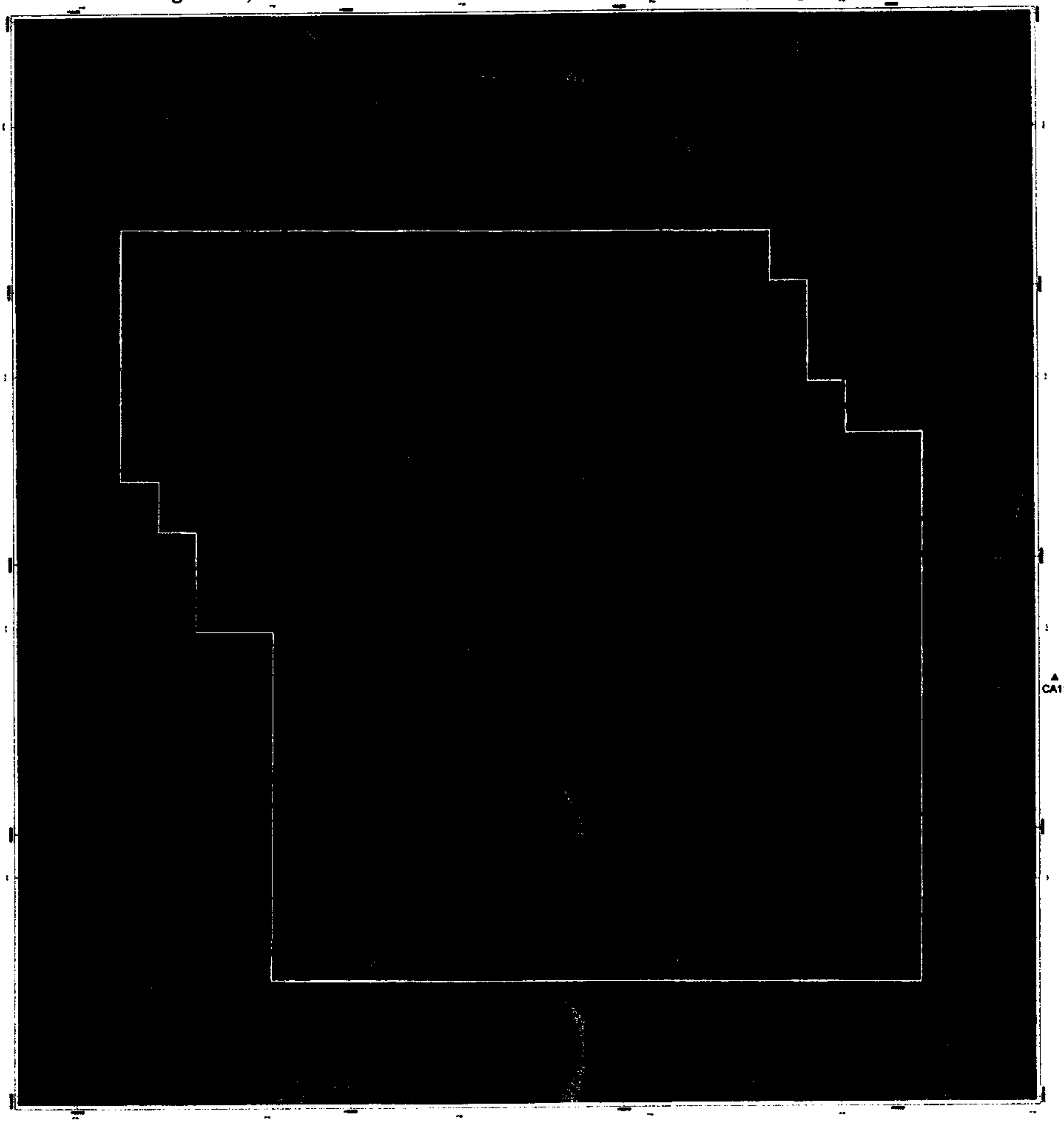


Figure 13) Vertical Derivative of Residual Gravity Anomaly Map (mGal/m)



MAP SYMBOL LEGEND

- Gravity Station - 1999 Field Program
- Gravity Station - NIMA Open File Data
- Magnetic Station - 1999 Field Program
- Mag Base Station - 1999 Field Program
- MT Site - 1999 Field Program

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Gravity Vertical Derivative (mGal/m)
Vertical Derivative Of Residual Gravity Anomaly

FOREST OIL INTERNATIONAL

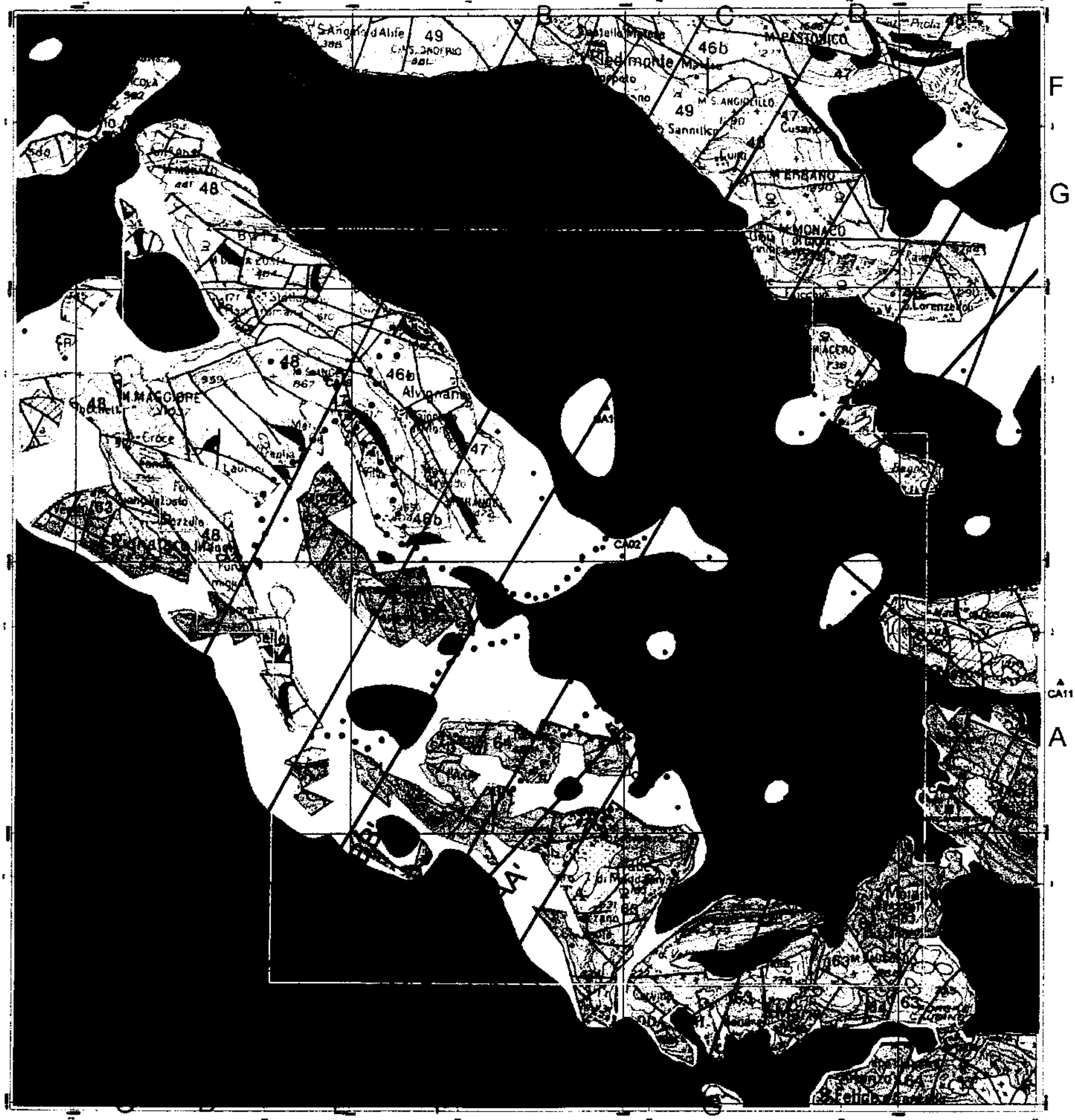
CASERTA BLOCK

Central Apennines - Southern Italy

GRAVITY VERTICAL DERIVATIVE - C.I. = 0.0006 mGal/m

Robert Pawlowski - 06/2000

Figure 14) 3-D Gravity Model Estimation of Depth to Carbonate (m subsea)



MAP SYMBOL LEGEND

- Gravity Station - 1999 Field Program
- Gravity Station - NIMA Open File Data
- Magnetic Station - 1999 Field Program
- Mag Base Station - 1999 Field Program
- MT Site - 1999 Field Program

Depth-To-Carbonate (meters subsea)

AOA Geophysics Inc.

FOREST OIL INTERNATIONAL

CASERTA BLOCK

Central Apennines - Southern Italy

Depth-To-Carbonate (Subsea) - C.I. = 250 m

Robert Pawlowski - 05/2000

Figure 15) GRANATH & Associates Geologic Structural Cross-Section A-A'

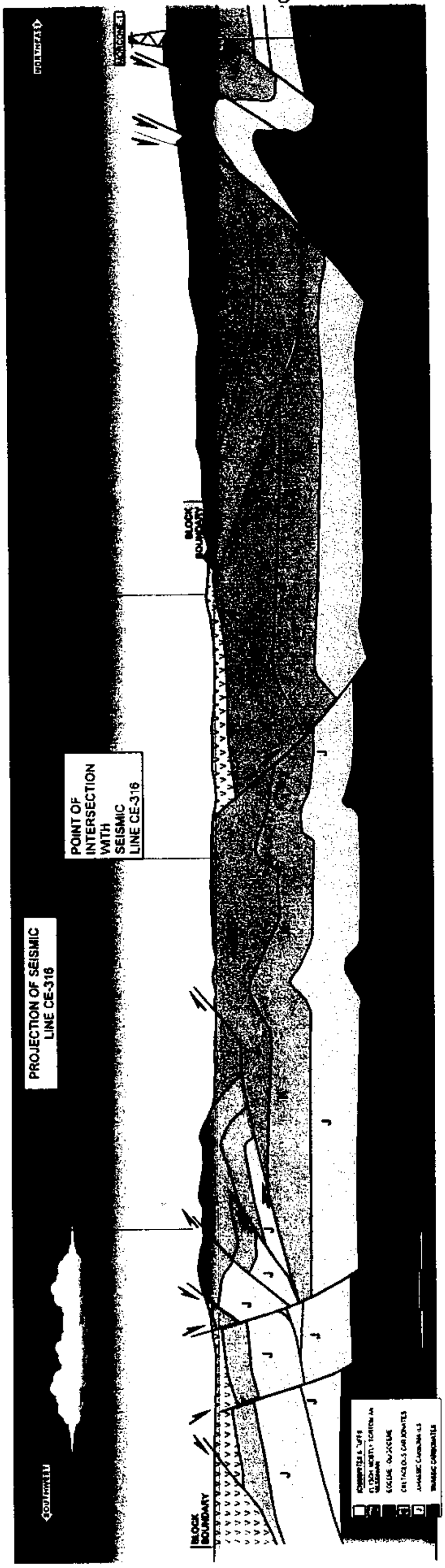


Figure 16) GRANATH & Associates Geologic Structural Cross-Section B-B'

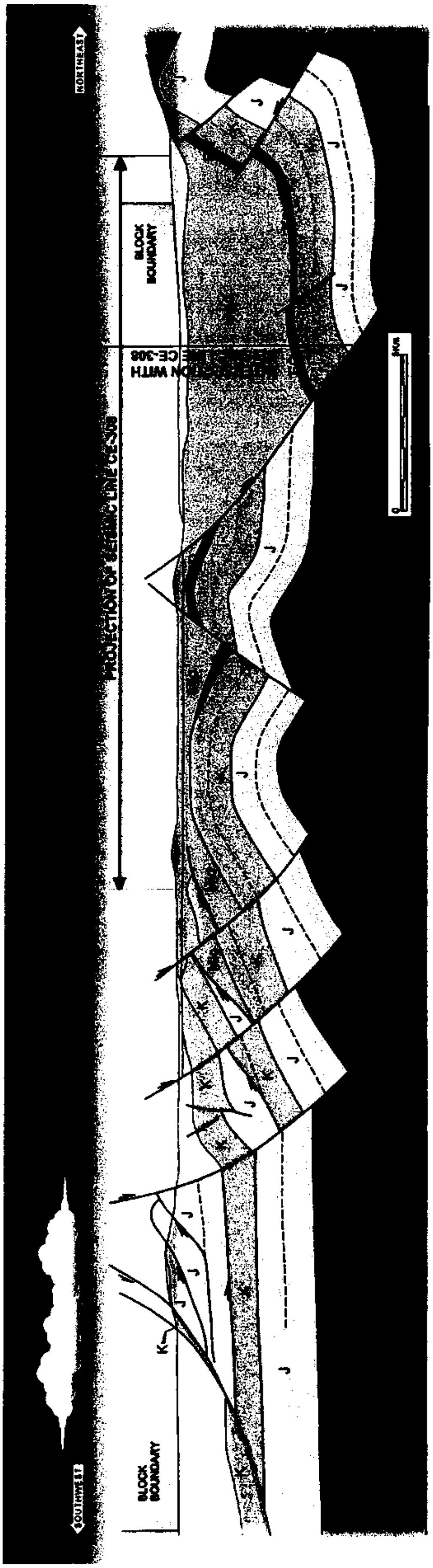


Figure 17) Gravity/Magnetic/MT Structural Model Cross-Section A

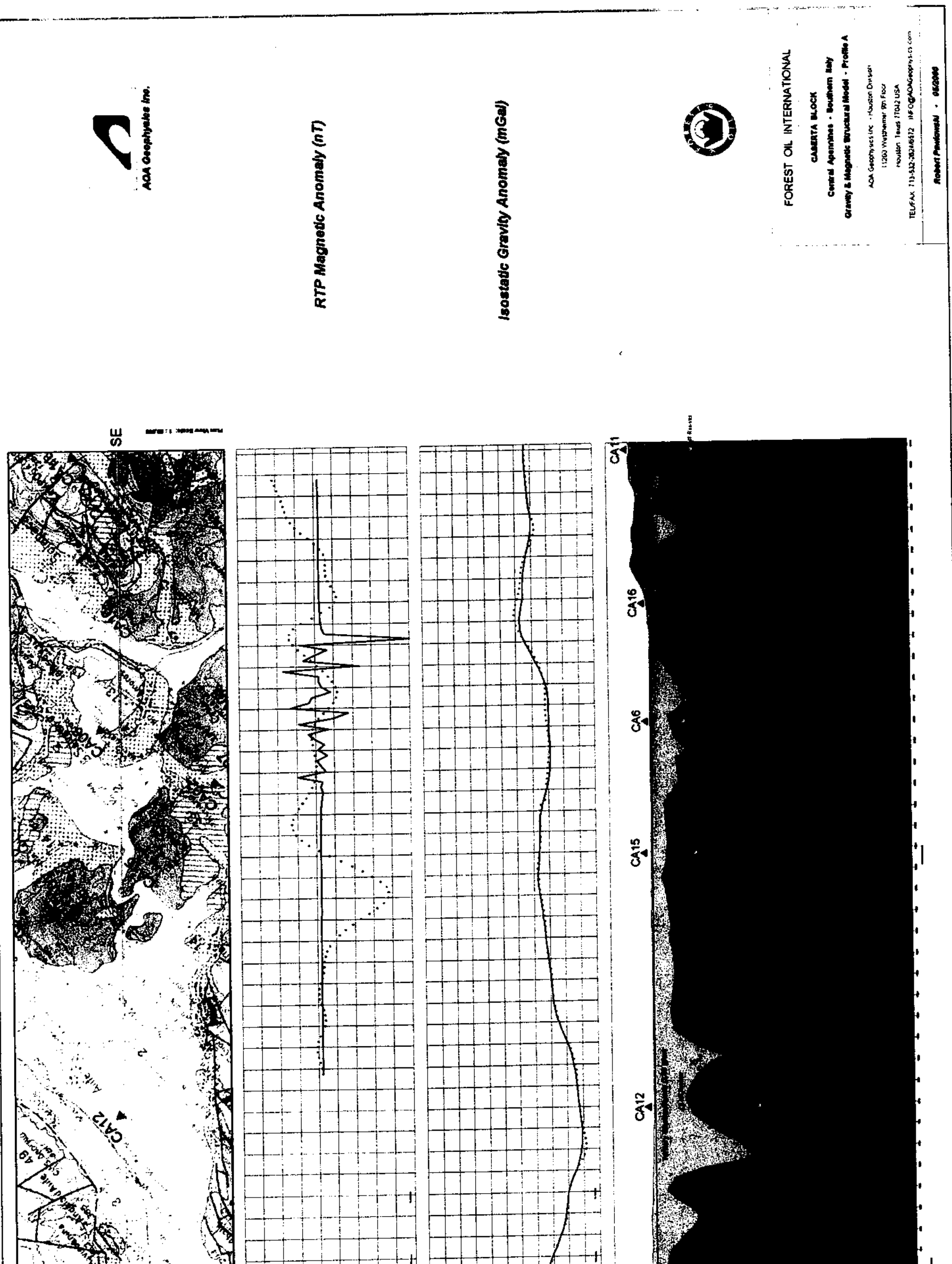


Figure 18) Gravity/Magnetic/MT Structural Model Cross-Section B

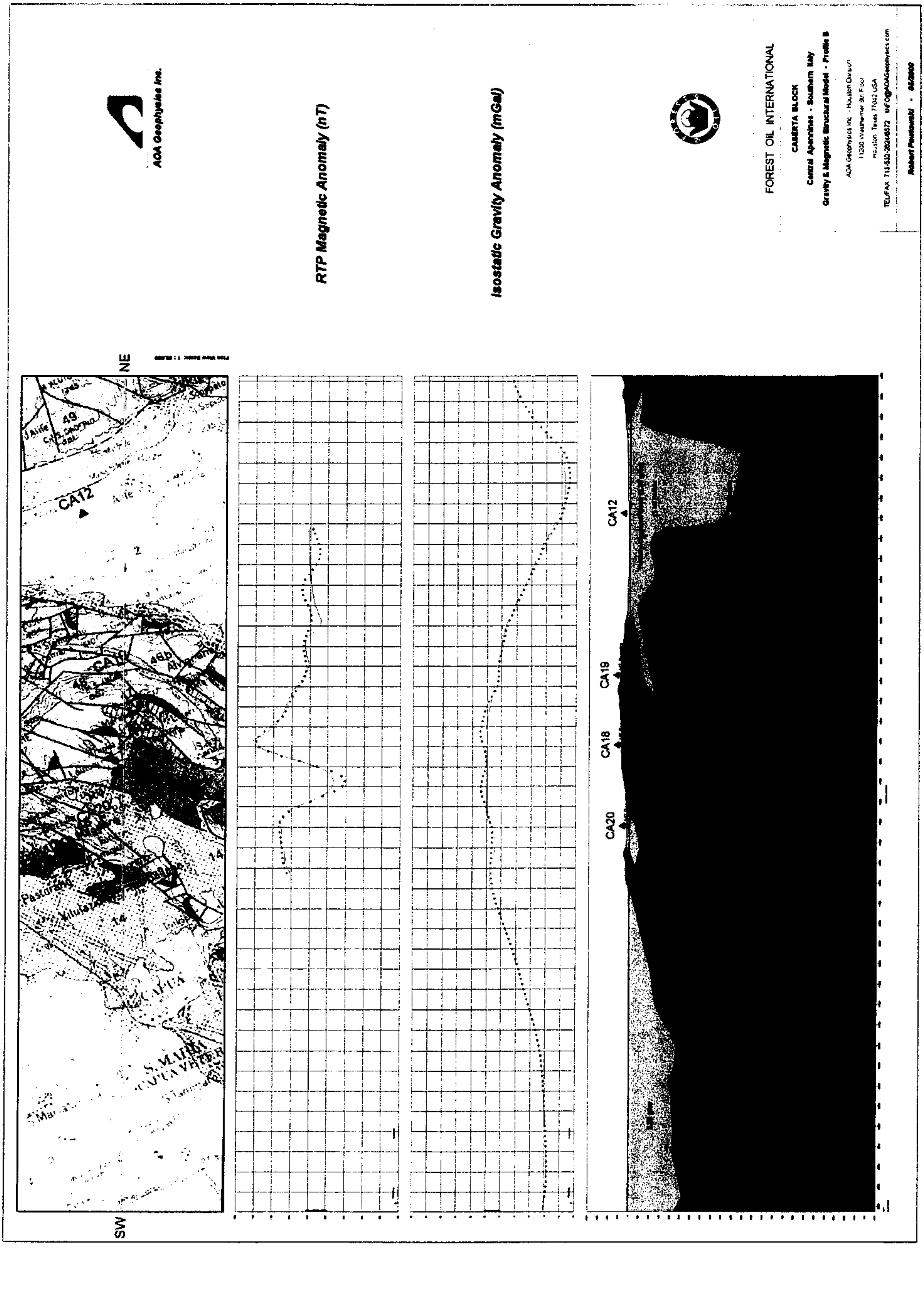


Figure 19) Gravity/Magnetic/MT Structural Model Cross-Section C

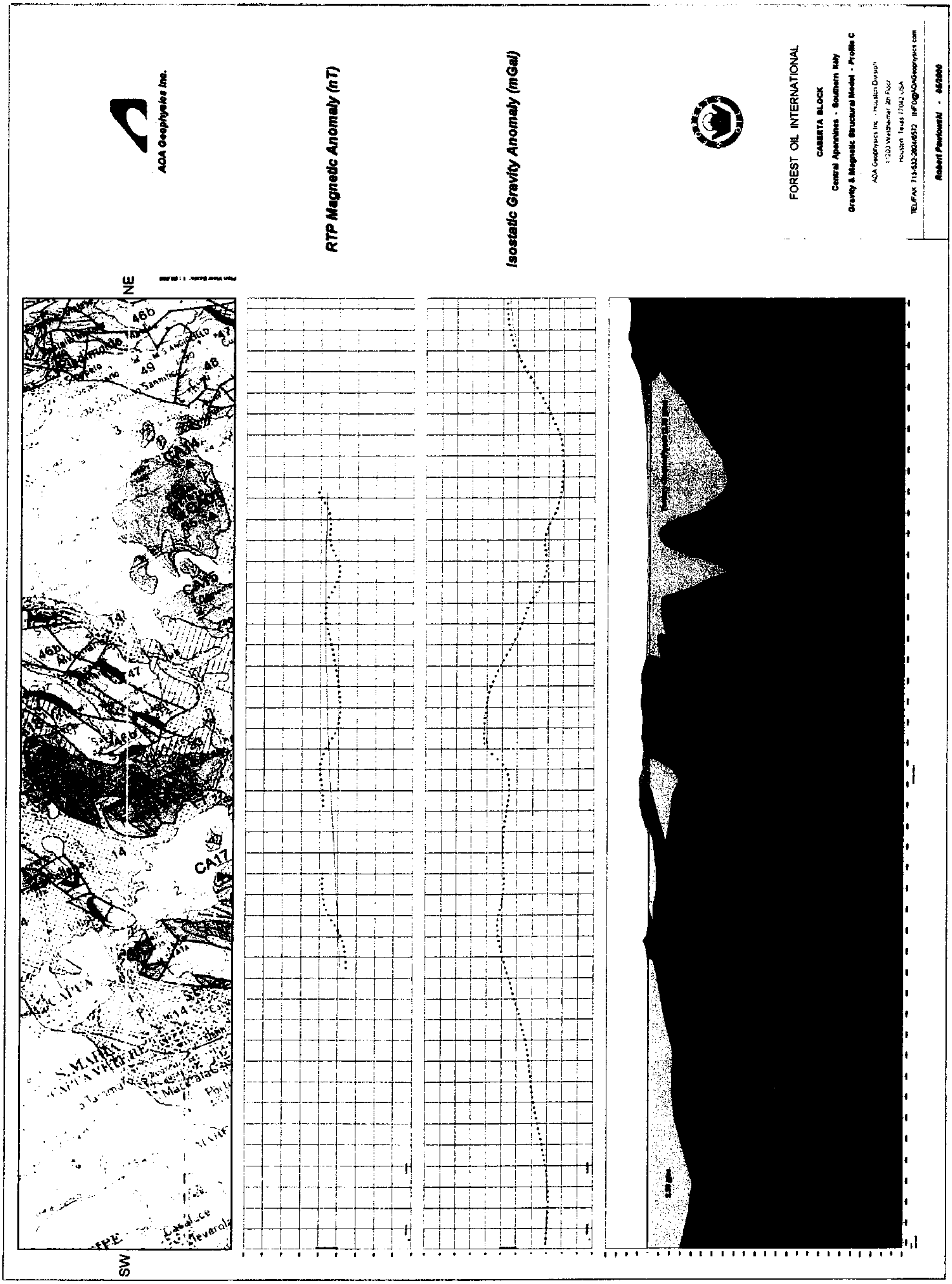


Figure 20) Gravity/Magnetic/MT Structural Model Cross-Section D

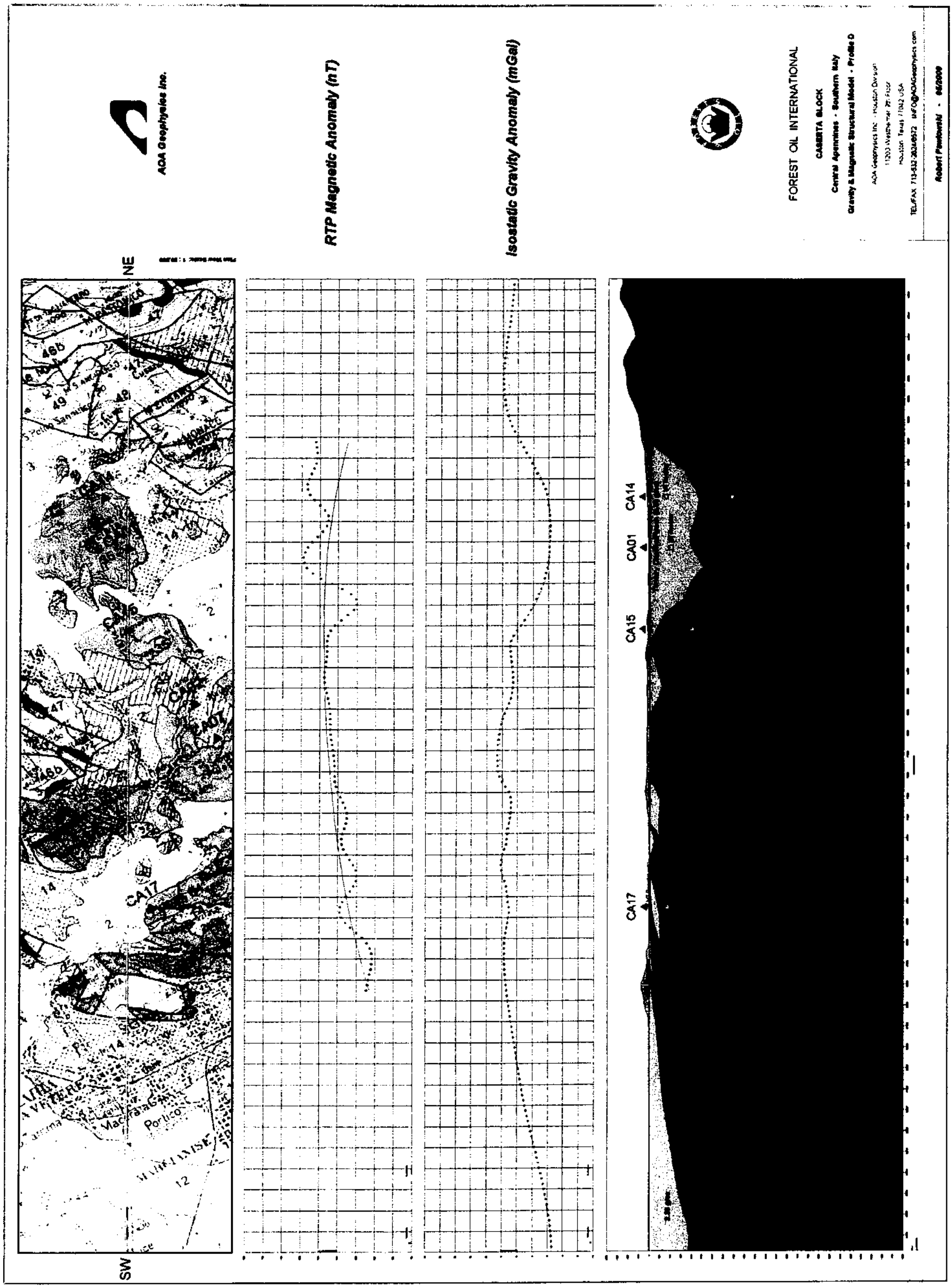


Figure 21) Gravity/Magnetic/MT Structural Model Cross-Section E

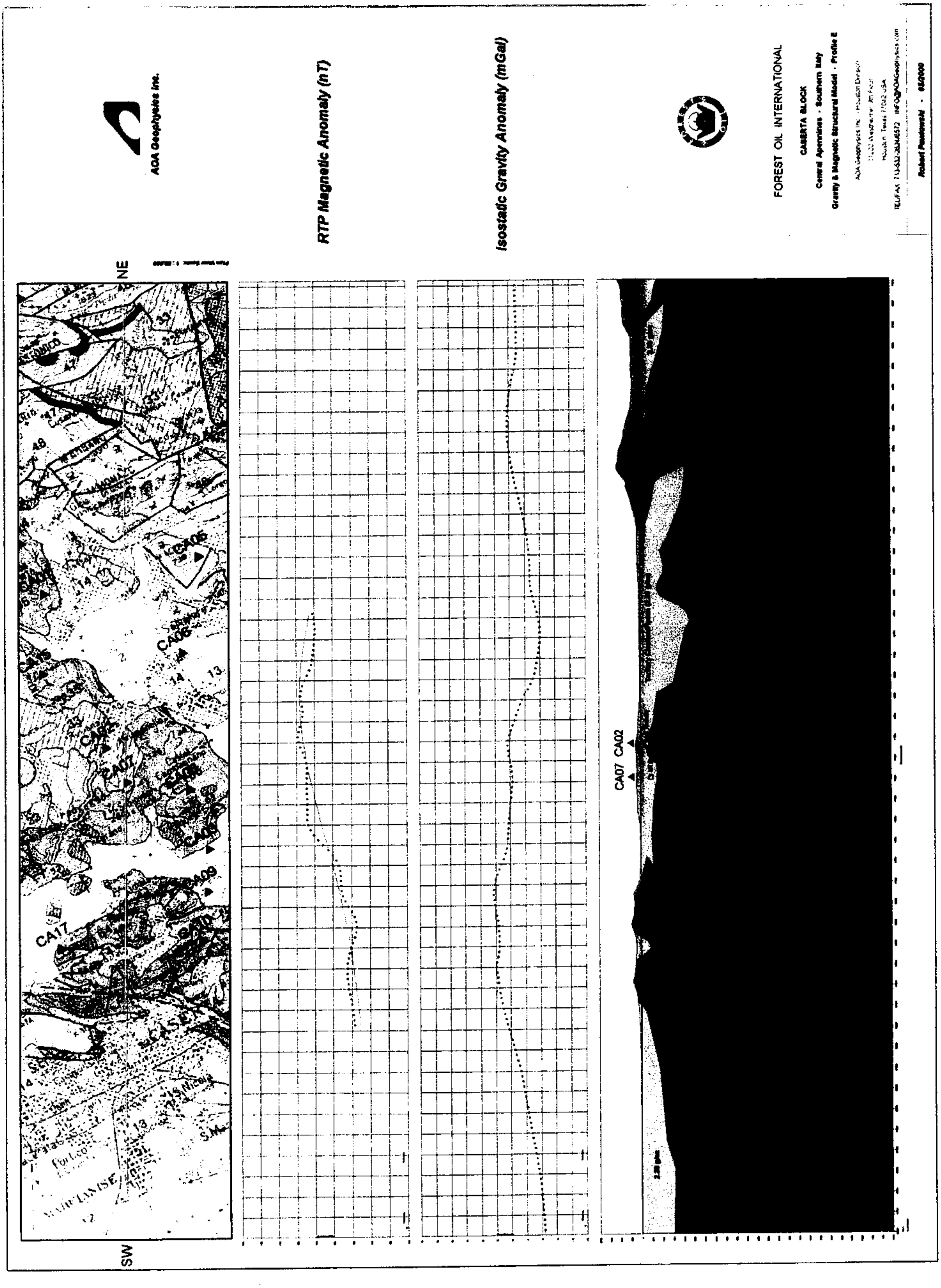


Figure 22) Gravity/Magnetic/MT Structural Model Cross-Section F

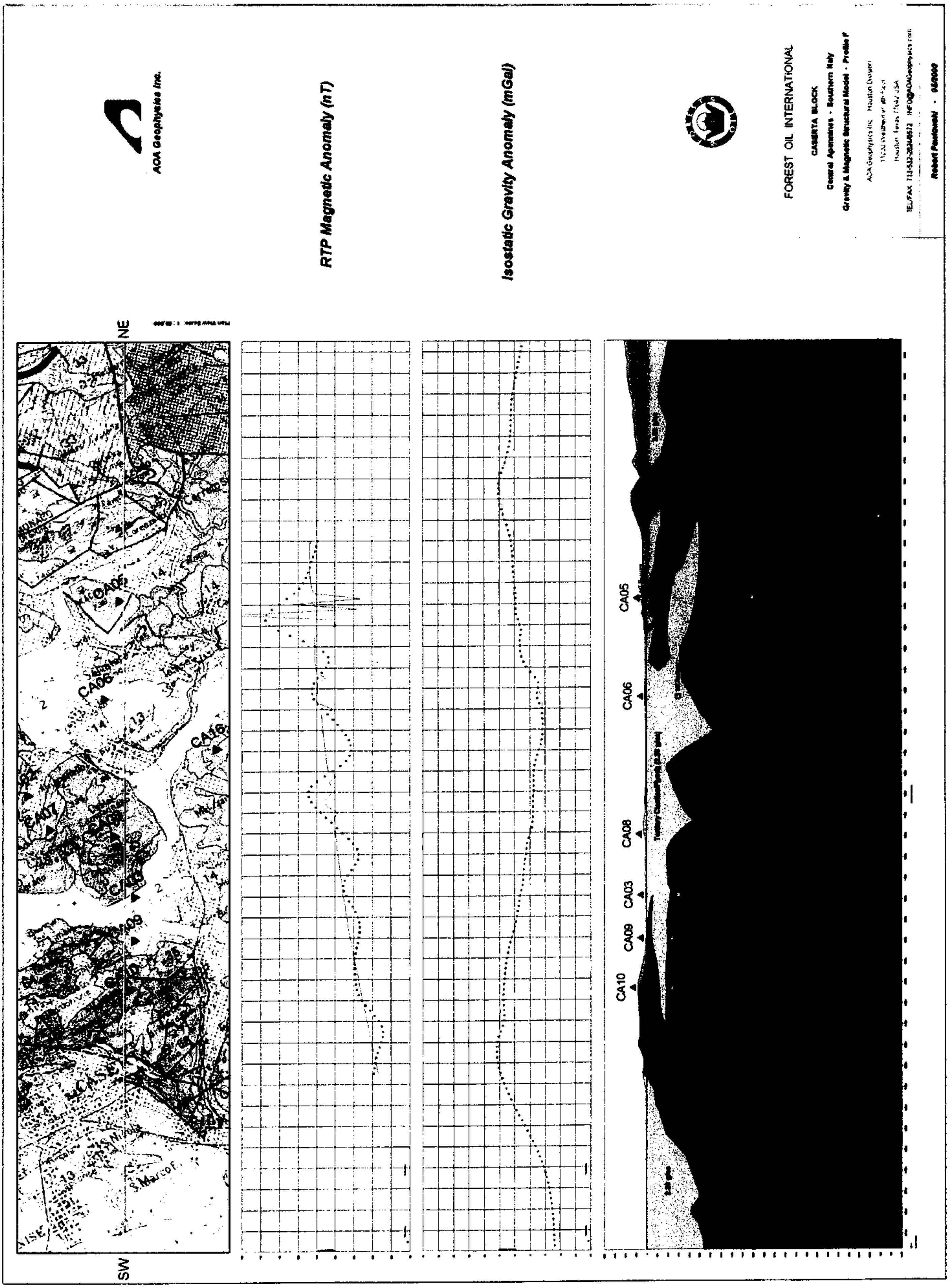


Figure 23) Gravity/Magnetic/MT Structural Model Cross-Section G

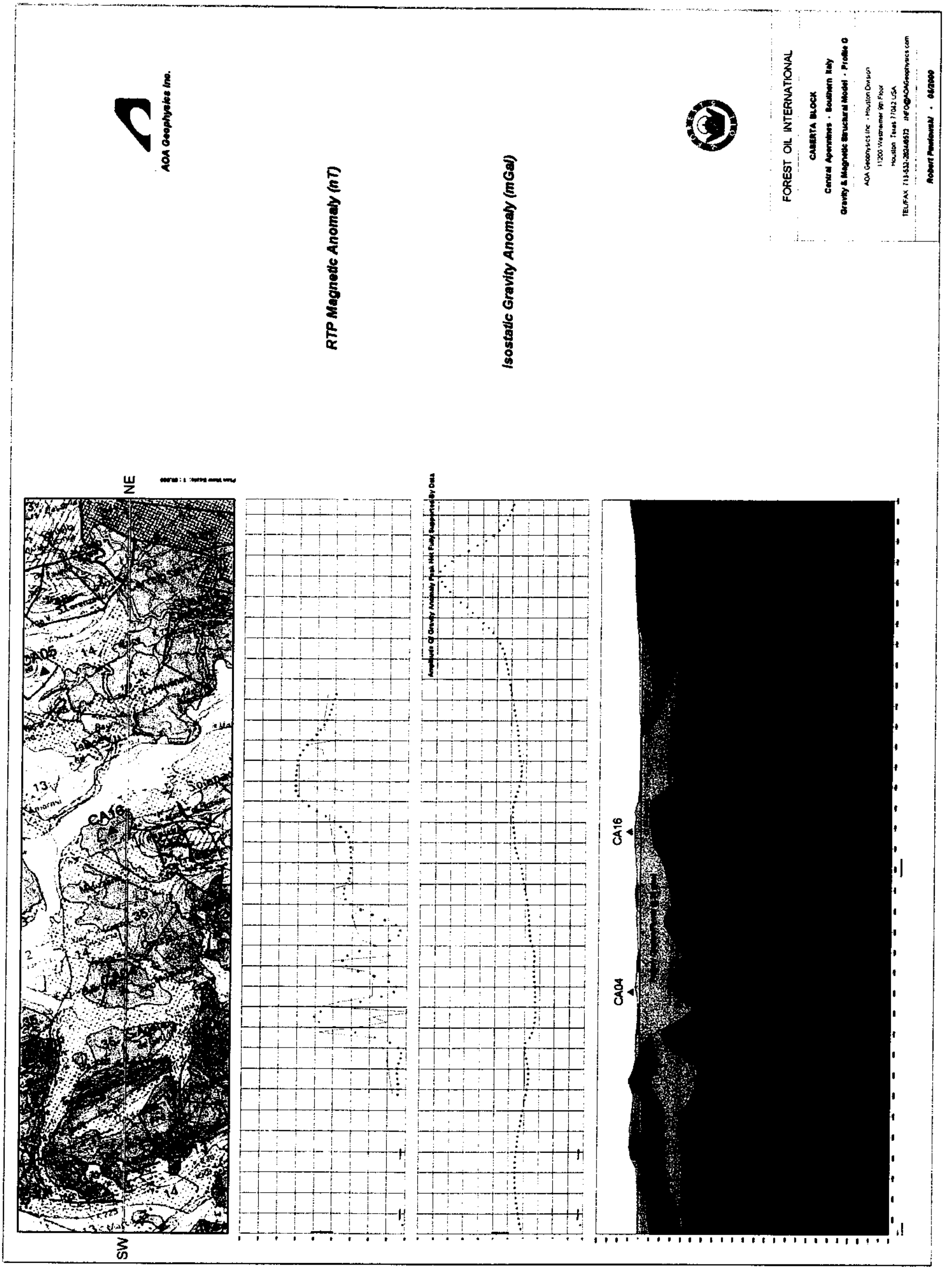
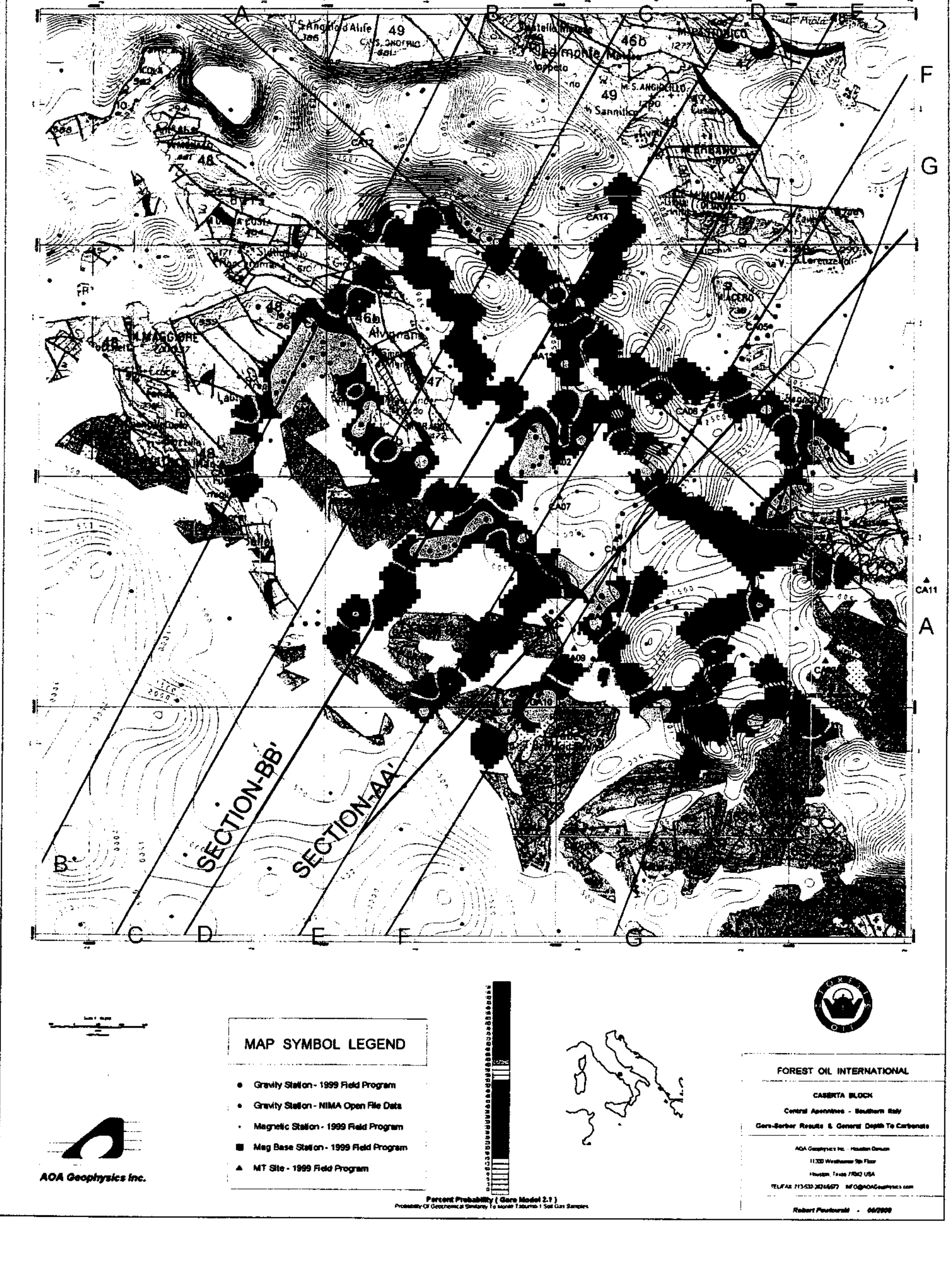


Figure 24) Gore-Sorber Petroliferous Probability Results



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