COLOMBIA:
The perfect ... environment for hydrocarbons

Open Round
COLOMBIA 2010

ANH
The people to speak to

Contents

HYDROCARBON POTENTIAL OF COLOMBIA

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Agenda

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- **Introduction and geologic setting**
- **Methodology**
- **Results**
- **Conclusions**

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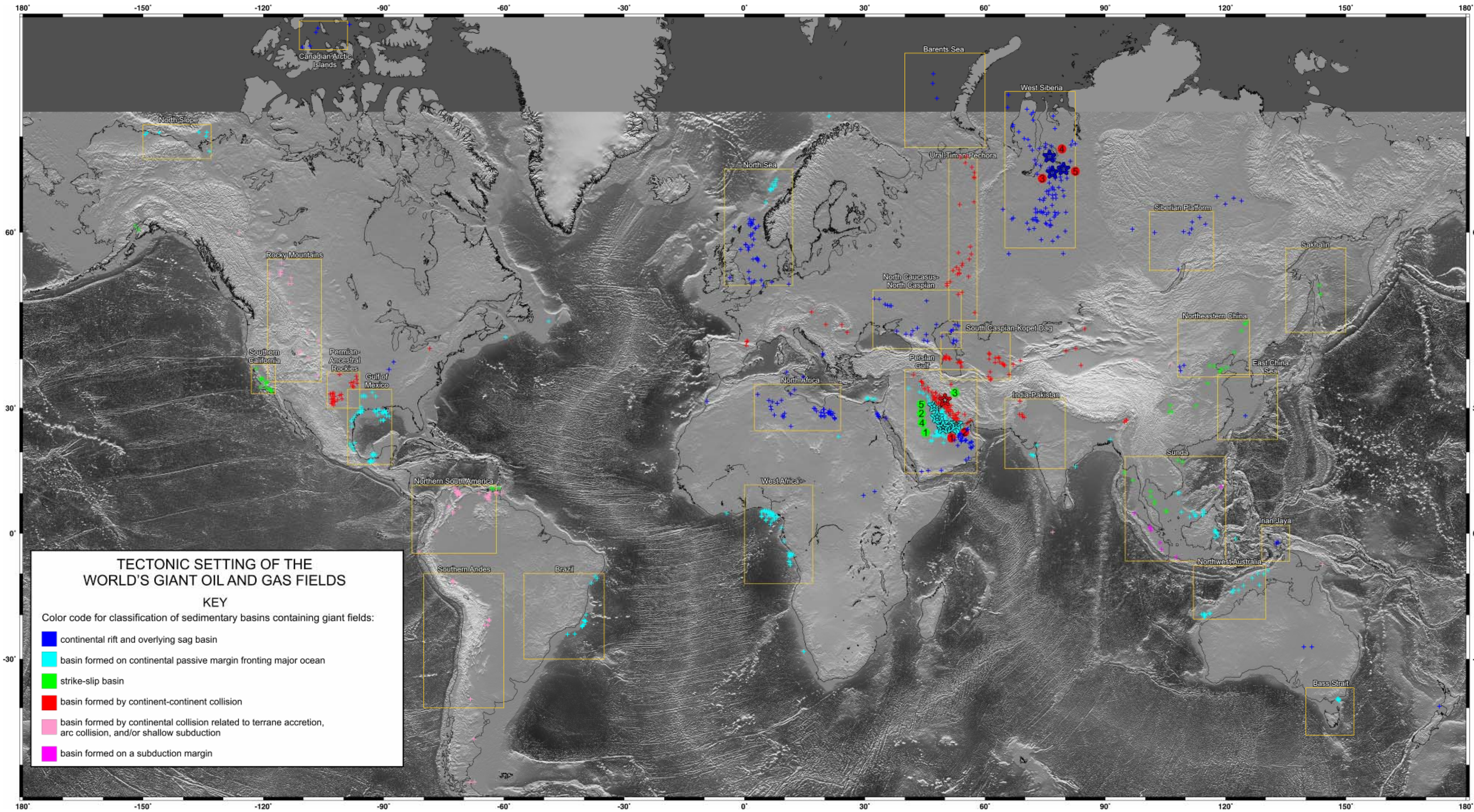
- **Introduction and geologic setting**
- **Methodology**
- **Results**
- **Conclusions**

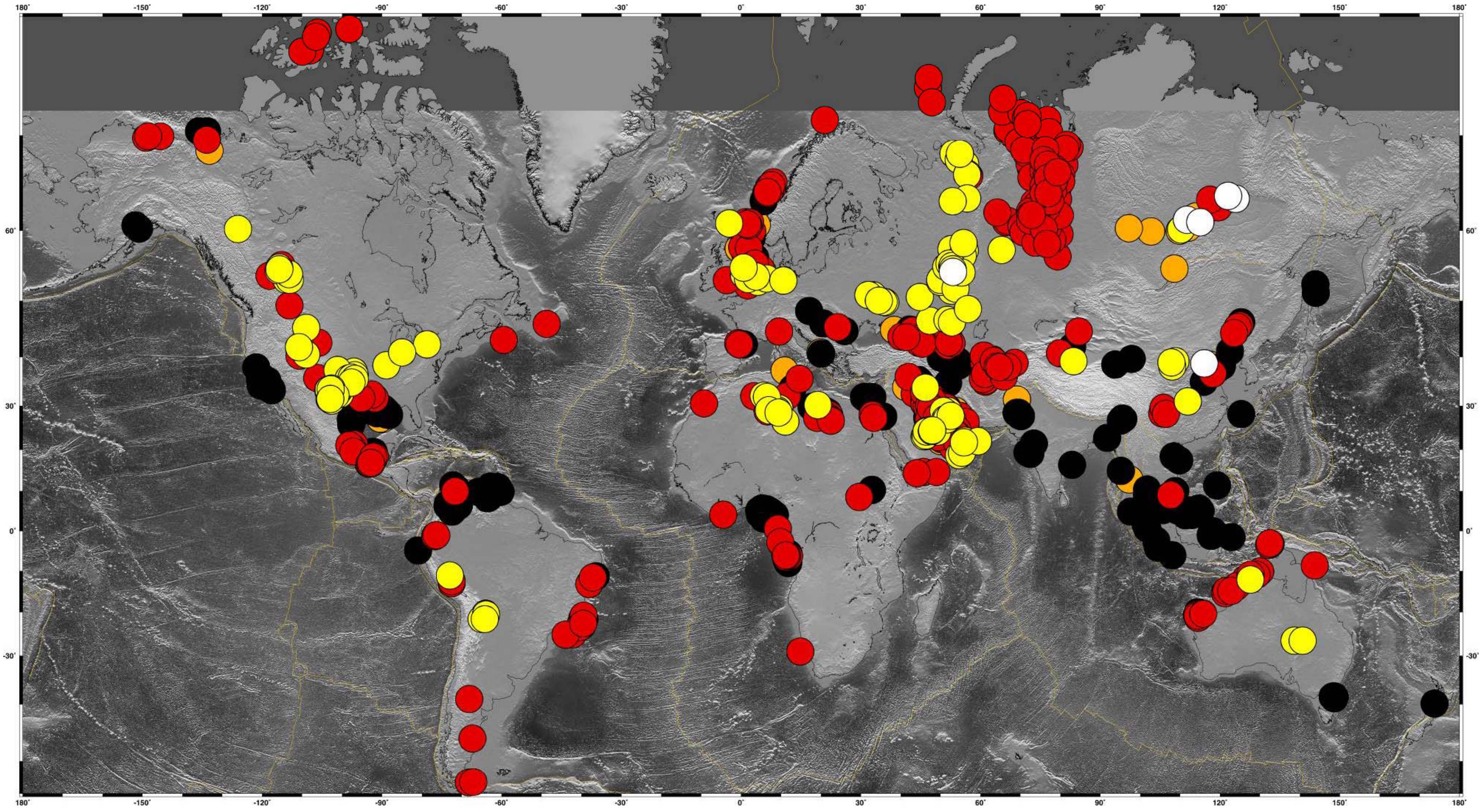
Giant fields classified by type of basin



Mann et al. (2003)

Giant fields classified by age

(911 Oil & Gas fields)



○ Precambrian ● Paleozoic ● Mesozoic ● Cenozoic

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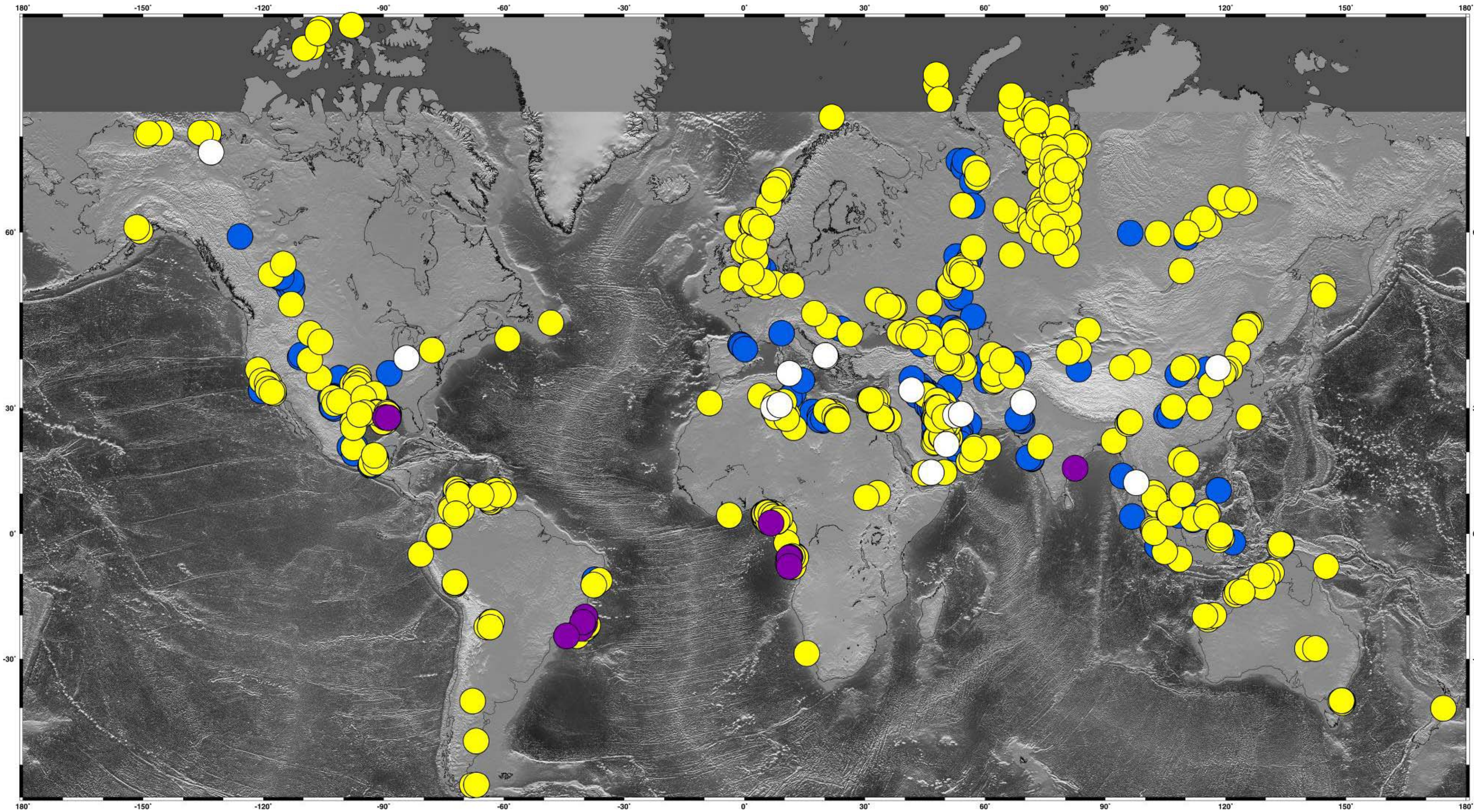
Giant fields classified by reservoir rocks

(911 Oil & Gas fields)



Carbonates   Sandstones   Turbidites   Others

Giant fields classified by trap

(911 Oil & Gas fields)

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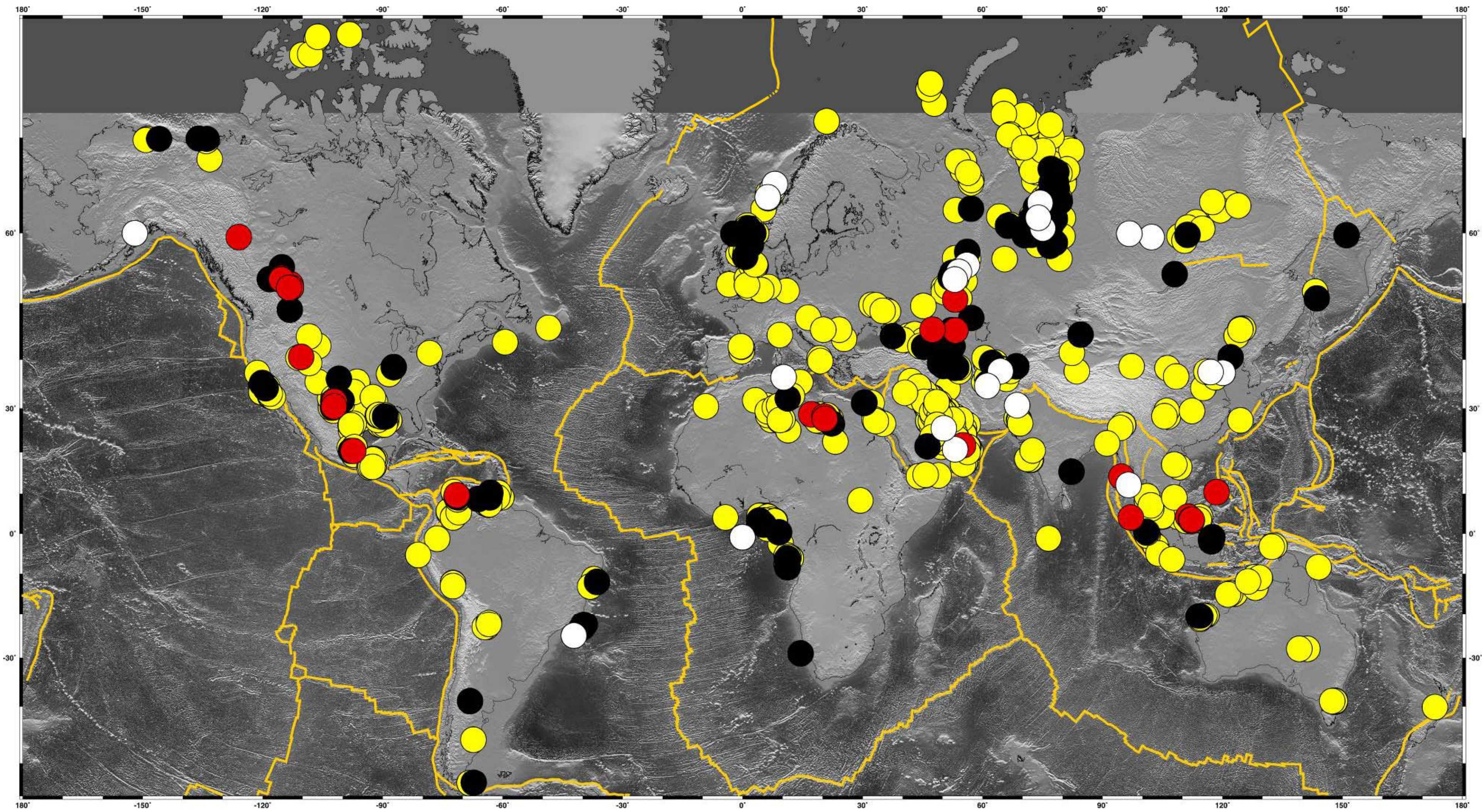

● Stratigraphic ● Structural ● Reef ○ Combined

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Giant fields classified by depth

(911 Oil & Gas fields)

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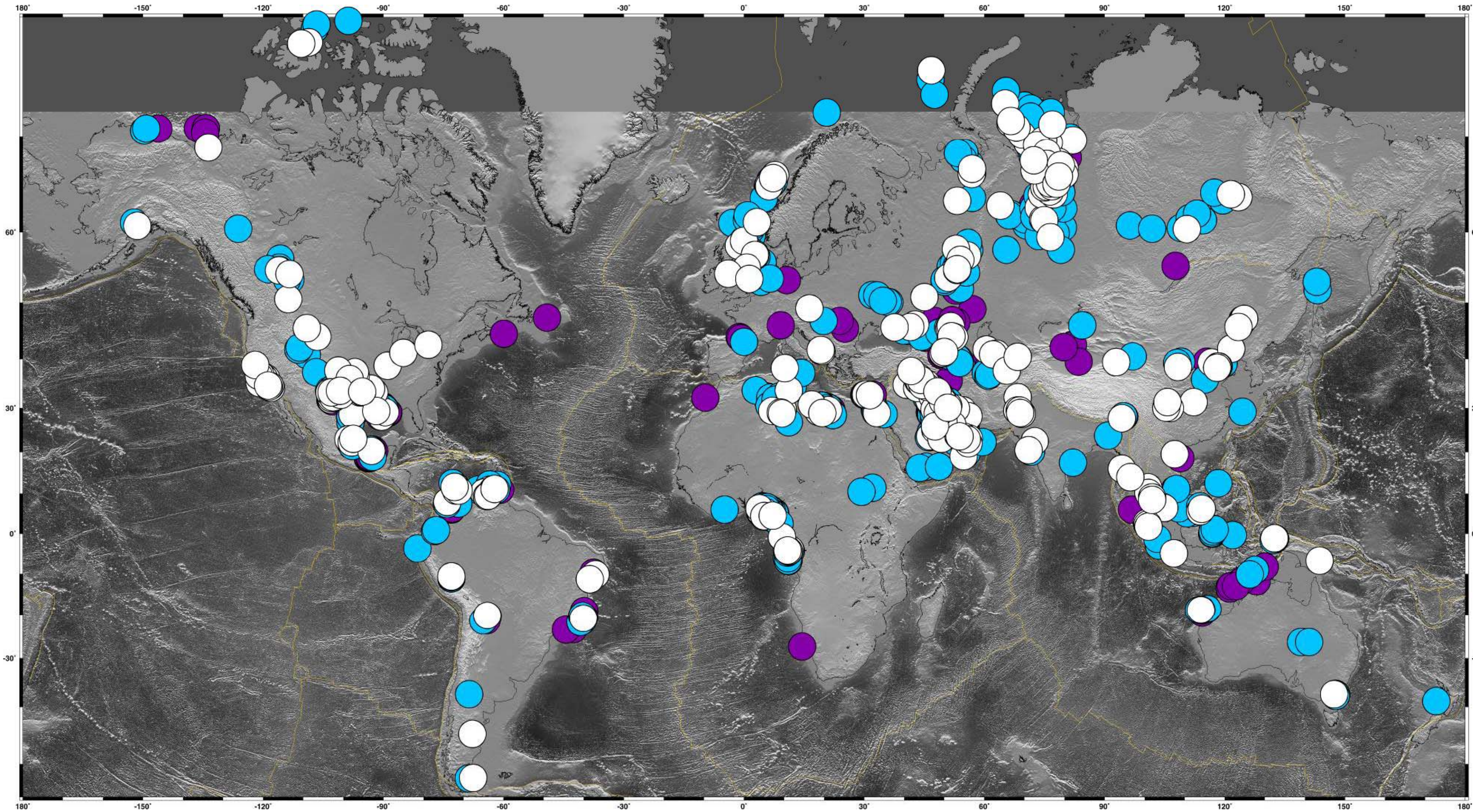

○ <1.5km   ● 1.5km ≤ depth < 3.0 km   ● > 3.0km

New patterns derived from incorporation of data in the frontier exploration's acres

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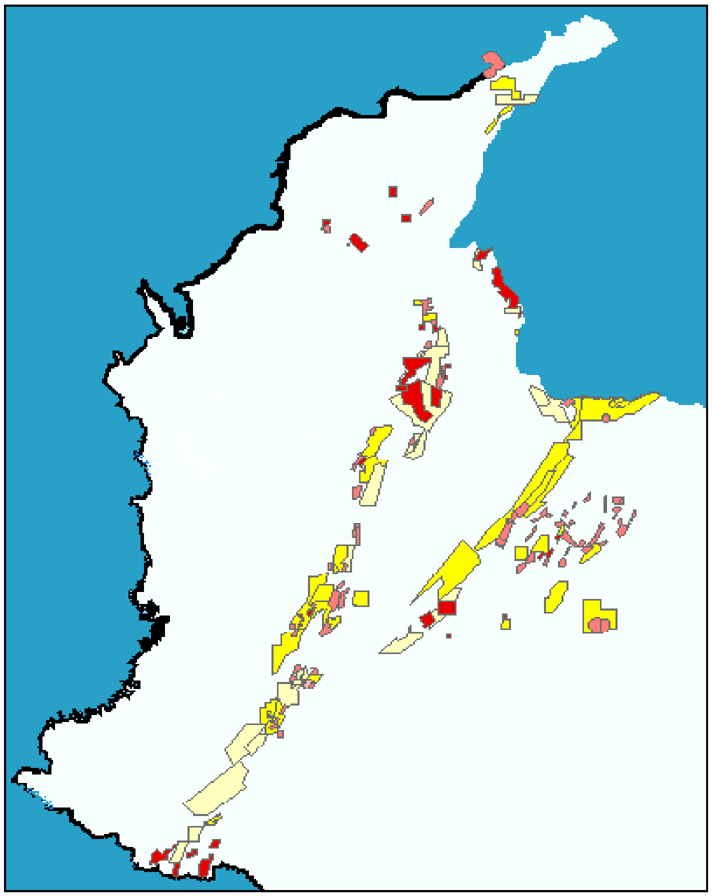
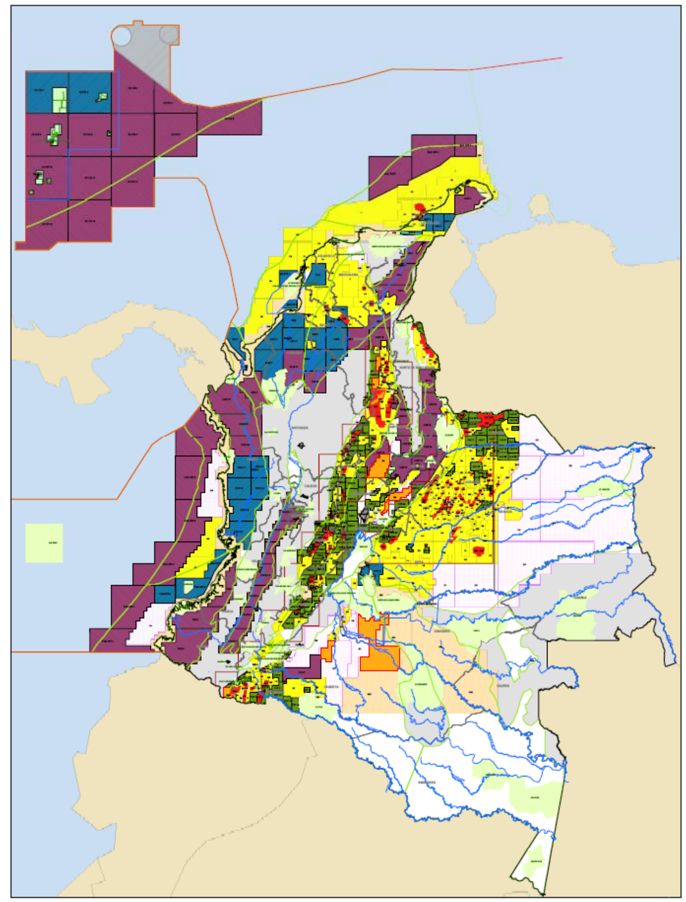
2003

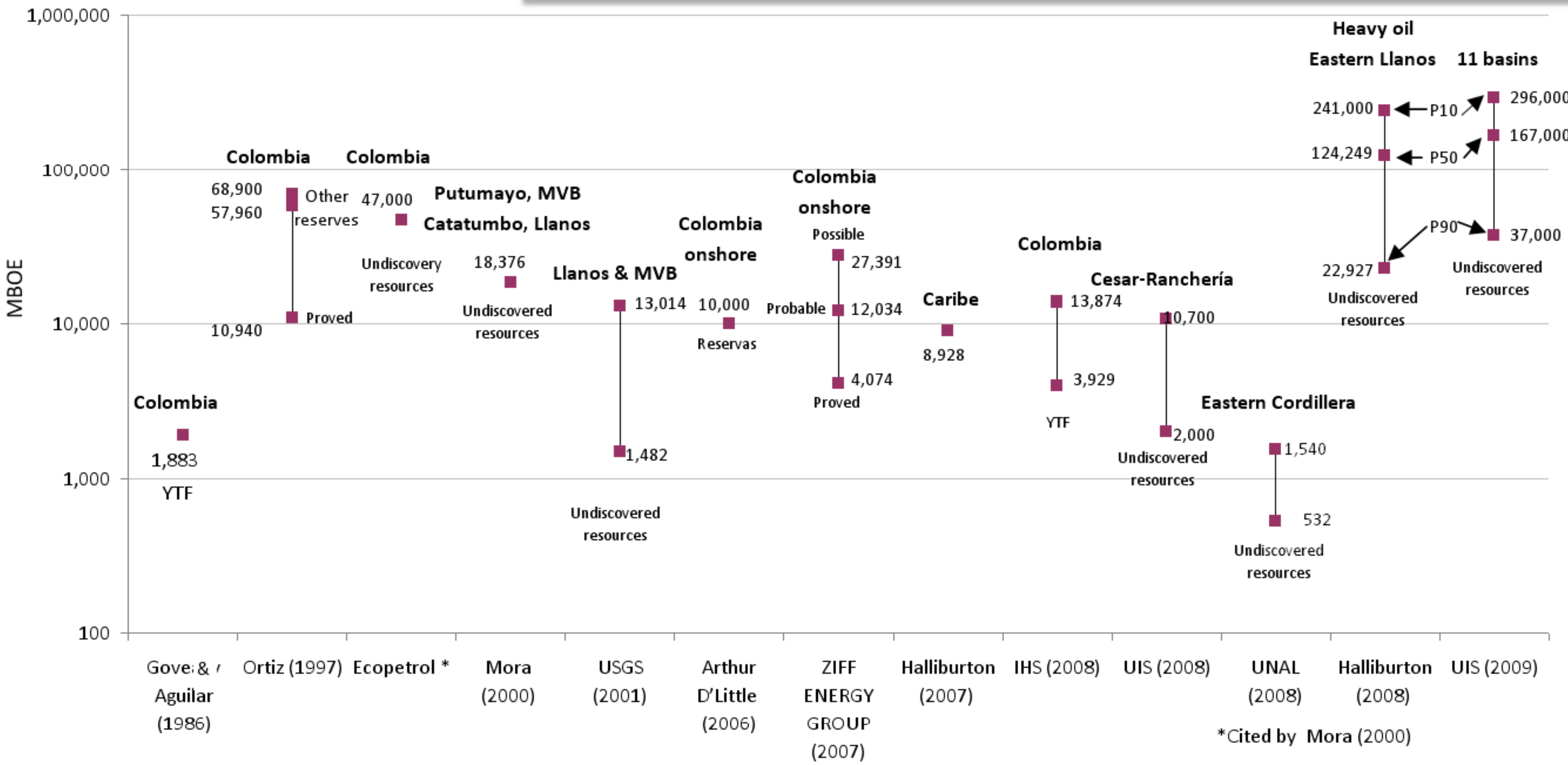


2010

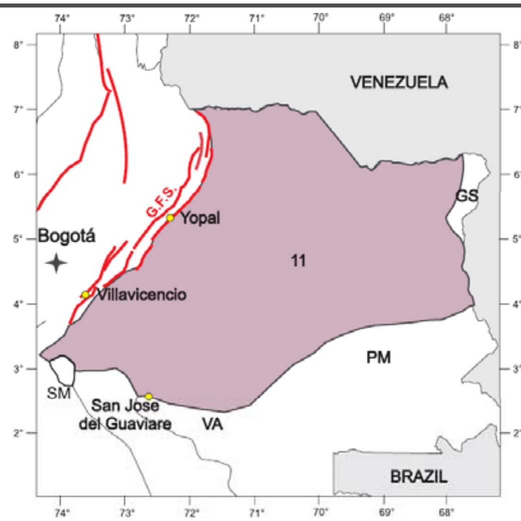


HC resources in Colombia

Different methodologies, different expectations and different results ...



Example: Eastern Llanos



- 8.300km 2D-seismic
- 36 wells
- Aero-geophysical data
- Geological and geochemical data

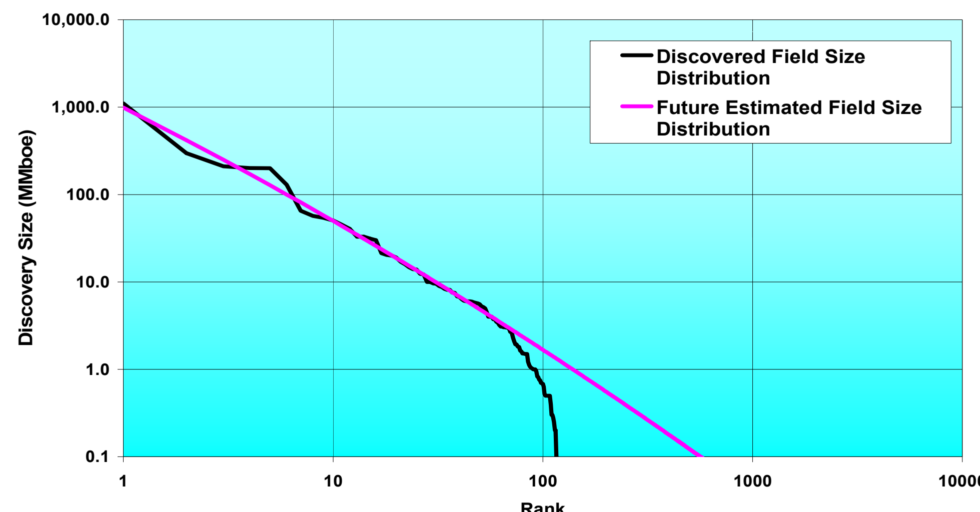
40 areas heavy oil prospects

YTFL	YTFB	YTFH
	MBOE	
421	500	2438

	STOIIP	GR	PRF
		MBOE	
P_{10}	708,947	54,044	8,760
P_{50}	3,518,916	122,057	22,927
P_{90}	6,830,048	222,203	57,850

Source: Halliburton (2008)

Field Size Distribution and Estimated Total Recoverable Eastern Llanos



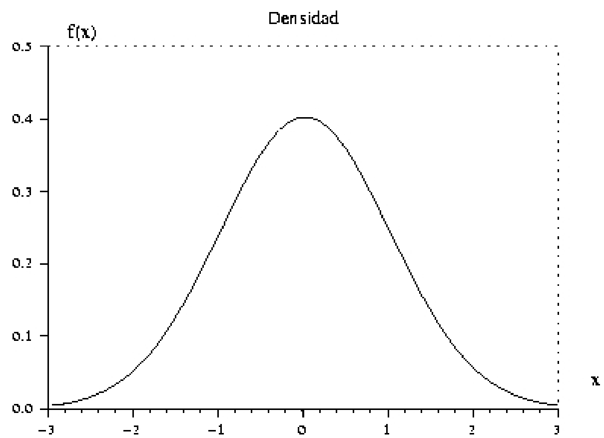
Source: IHS (2008)

Agenda

- Introduction and geologic setting
- **Methodology**
- Results
- Conclusions

Methodology: Montecarlo

$$OOIP = \frac{7758 * \phi * A * h * (1 - S_w)}{B_{oi}}$$



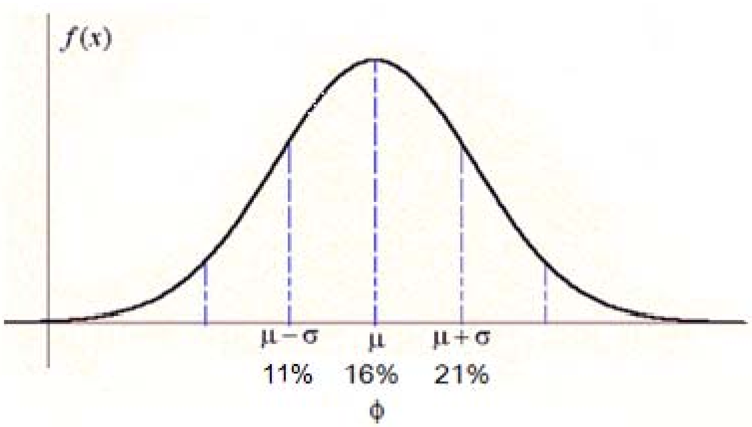
High variability and uncertainty of variables

Geologic risk

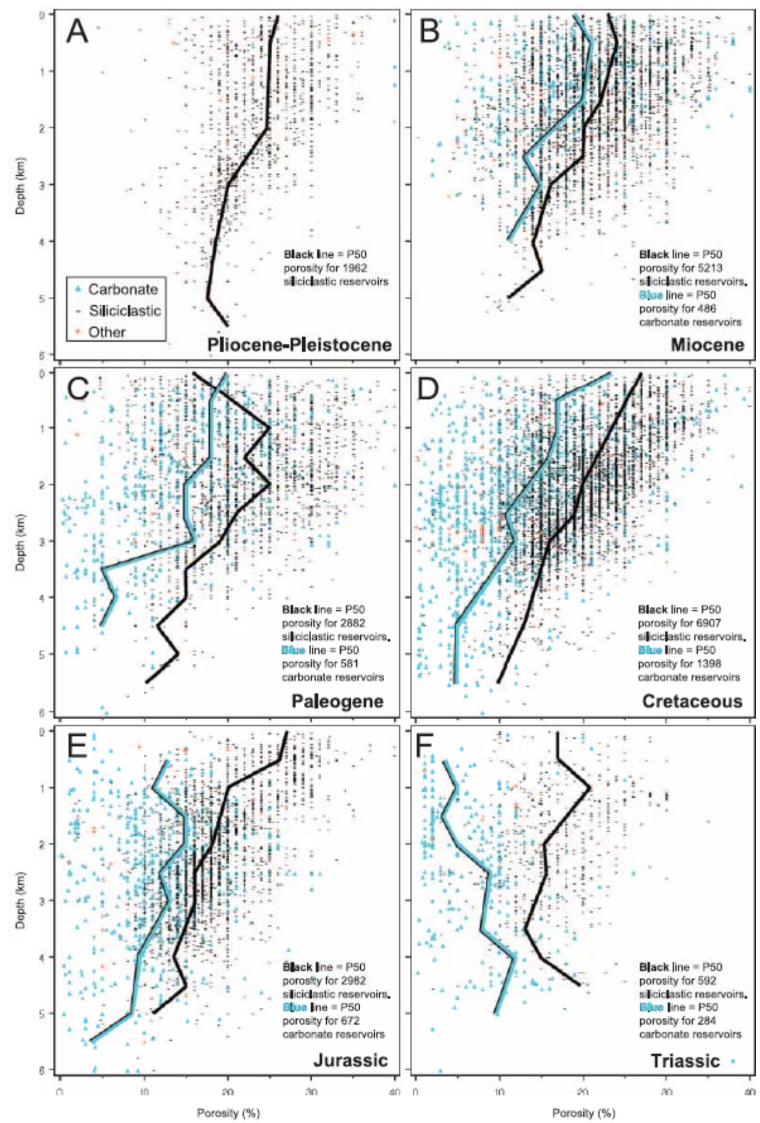
Recovery factor

Porosity

$$OOIP = \frac{7758 * \phi * A * h * (1 - S_w)}{B_{oi}}$$



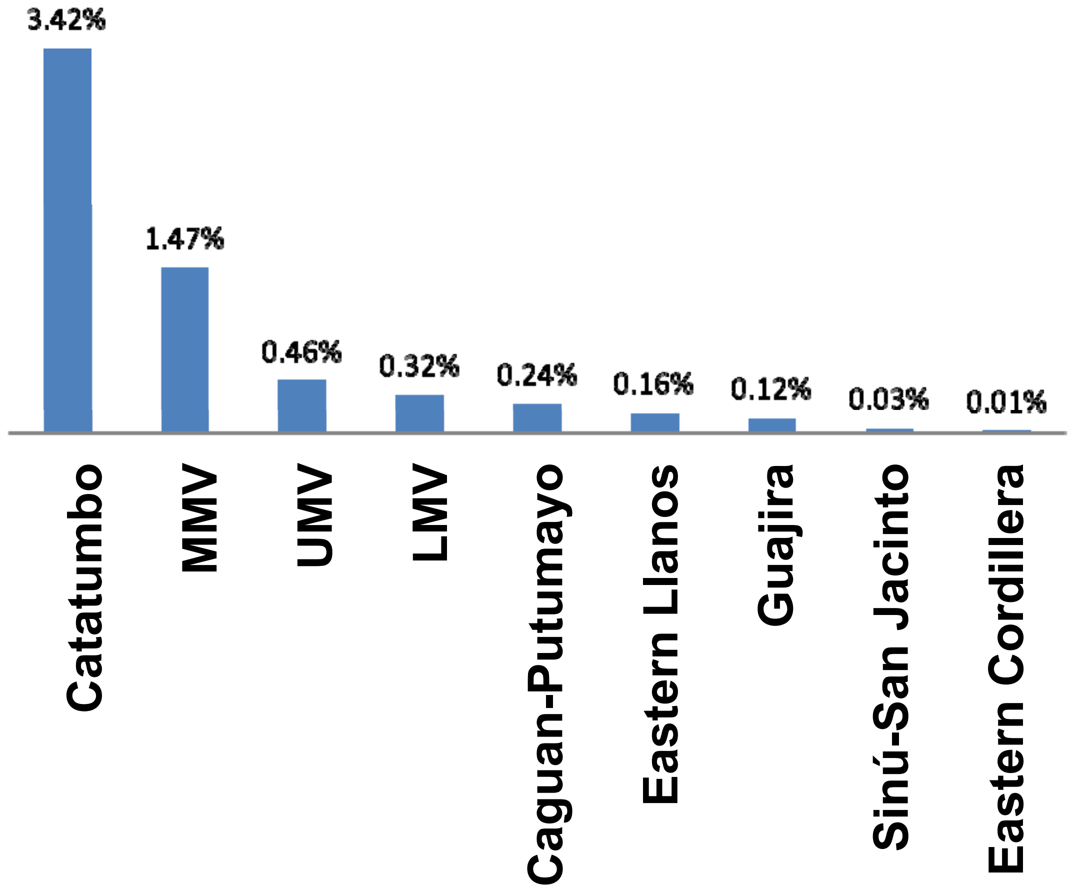
Petroleum reservoir porosity versus depth: Influence of geological age. AAPG Bulletin, v. 93, no. 10 (October 2009), pp. 1281–1296.



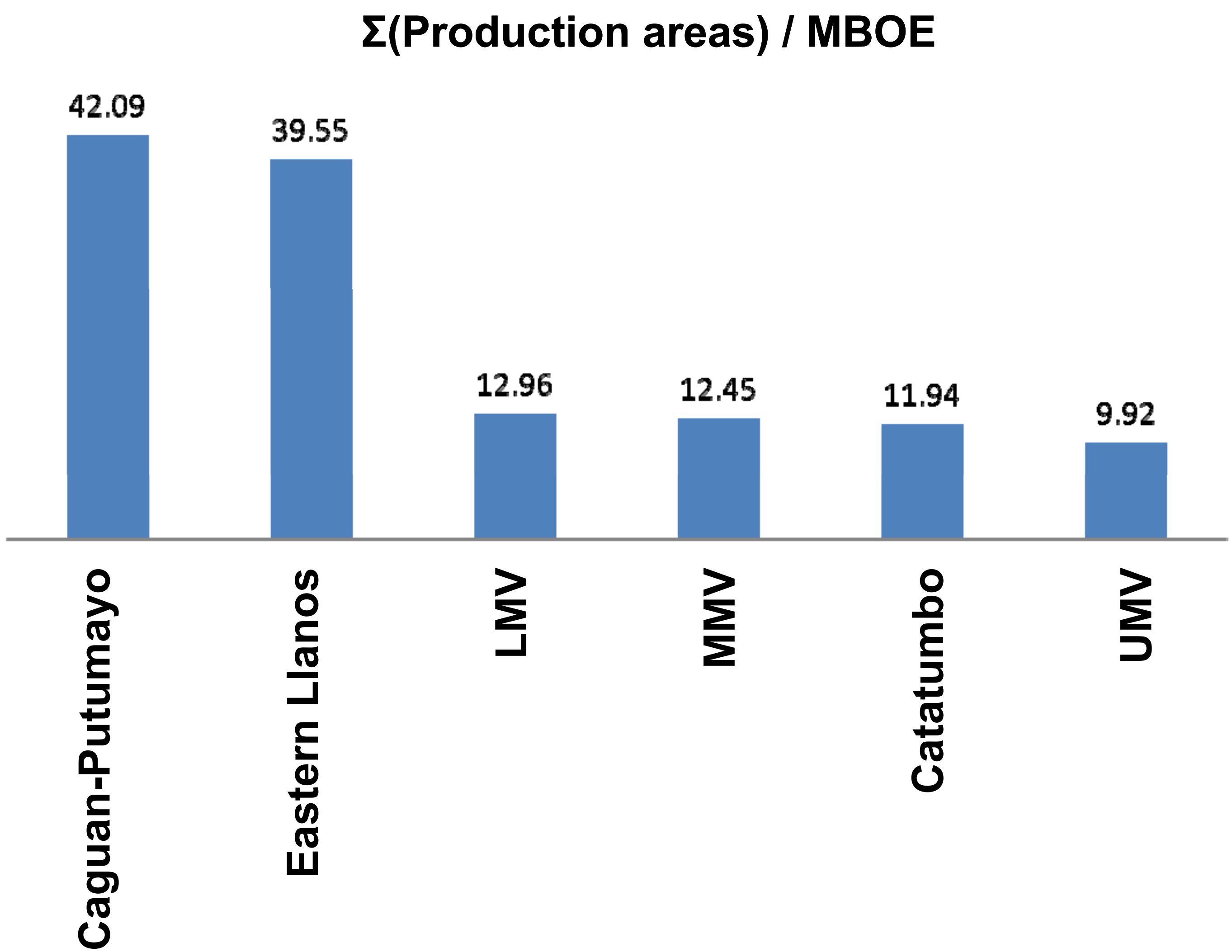
Corollary 1

$$OOIP = \frac{7758 * \phi * A * h * (1 - S_w)}{B_{oi}}$$

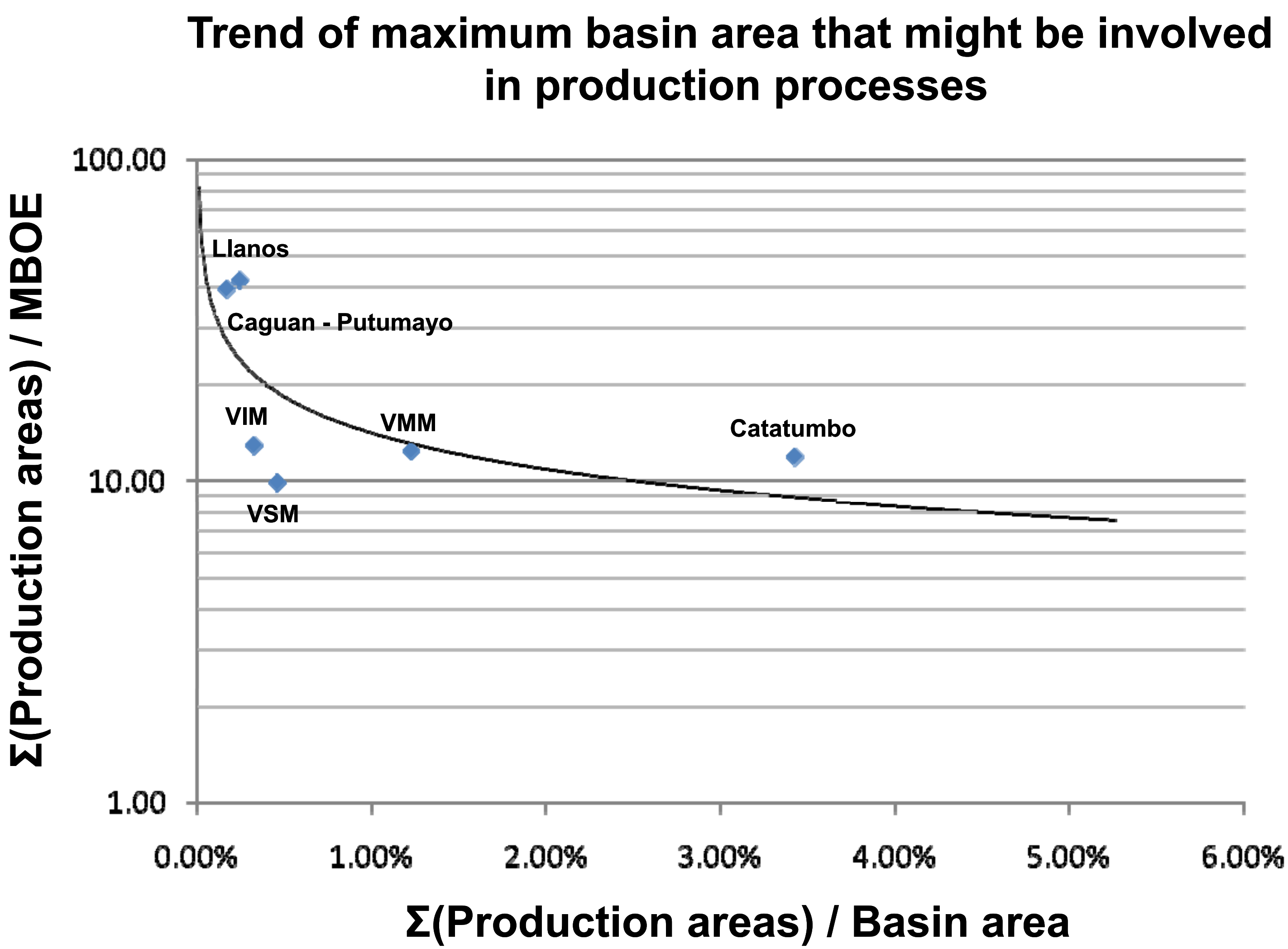
Σ(Production areas) / Basin area



Corollary 2


Σ(Production areas) / MBOE
42.09
39.55
12.96
12.45
11.94
9.92
Caguan-Putumayo
Eastern Llanos
LMV
MMV
Catatumbo
UMV

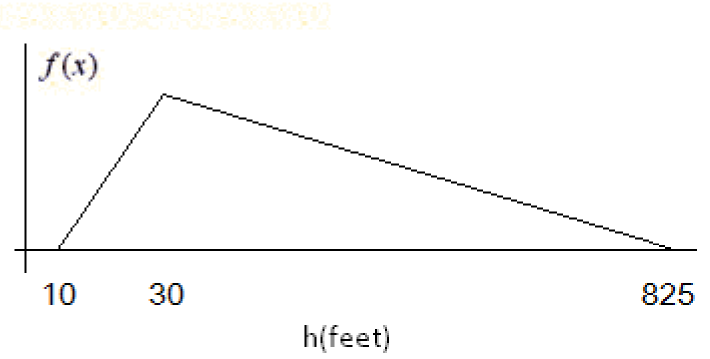
Hypothesis

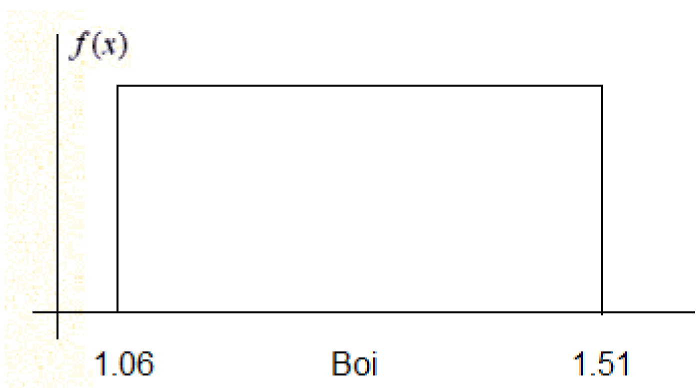


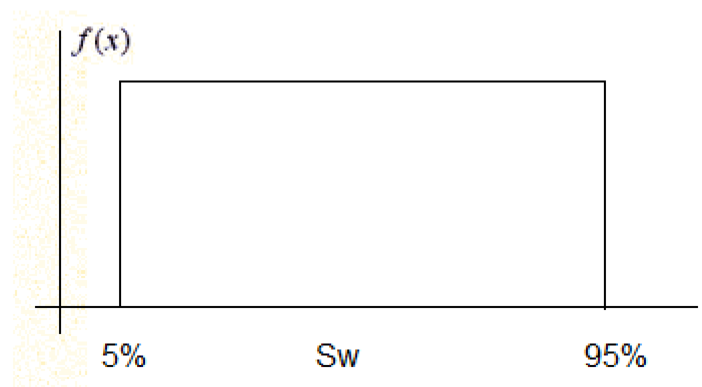
Trend of maximum basin area that might be involved in production processes
Σ(Production areas) / MBOE
100.00
10.00
1.00
Llanos
Caguan - Putumayo
VIM
VMM
Catatumbo
VSM
0.00%
1.00%
2.00%
3.00%
4.00%
5.00%
6.00%
Σ(Production areas) / Basin area

PDF of *h*, S_w and B_{oi}

$$OOIP = \frac{7758 * \phi * A * h * (1 - S_w)}{B_{oi}}$$







Questions that arise from the assumed hypothesis

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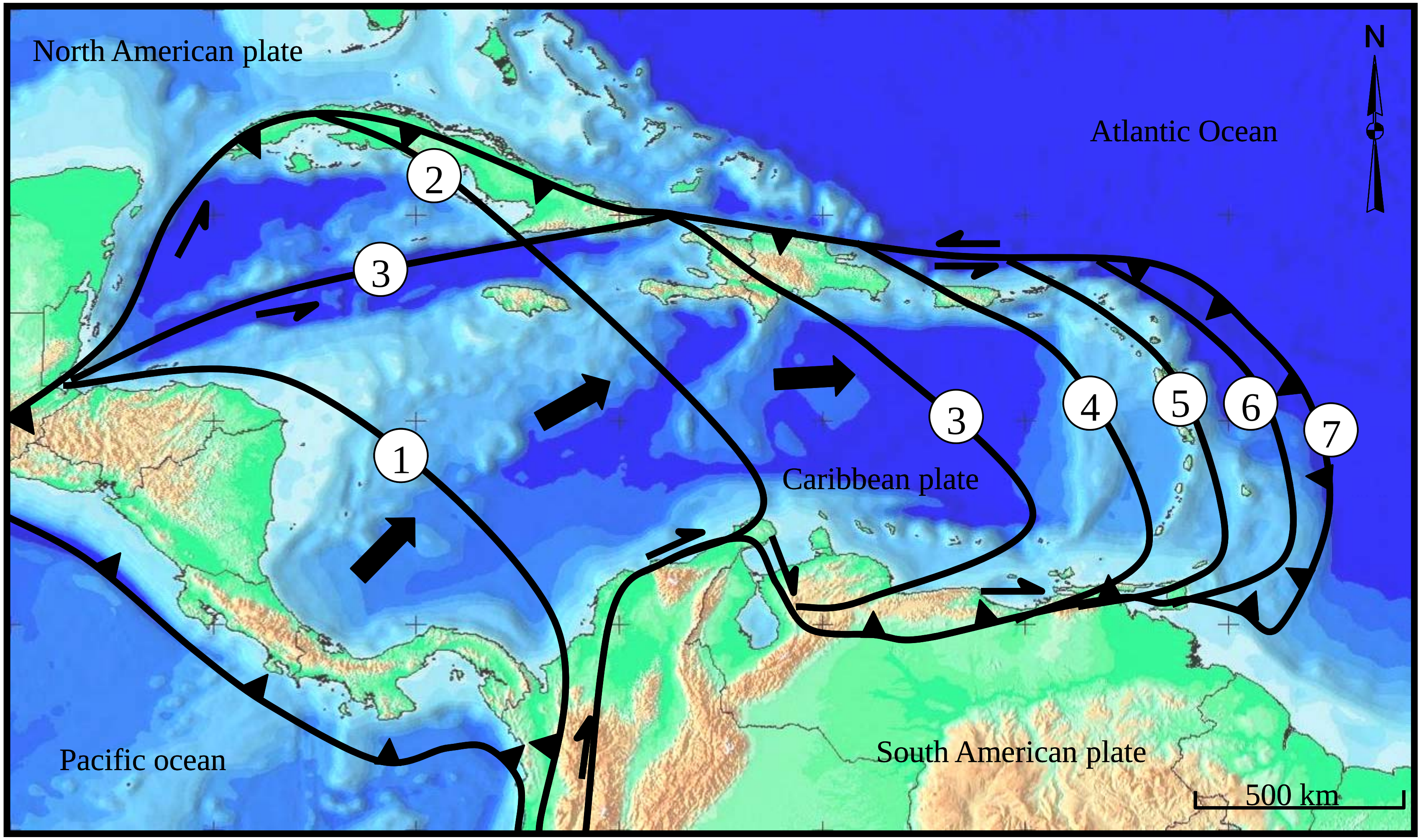
1. How to support with geologic evidence, the observation that production acres are limited to up to 6% of the total area in the Colombian basins?

2. Has there been enough HC generated for supporting the YTF expectations?

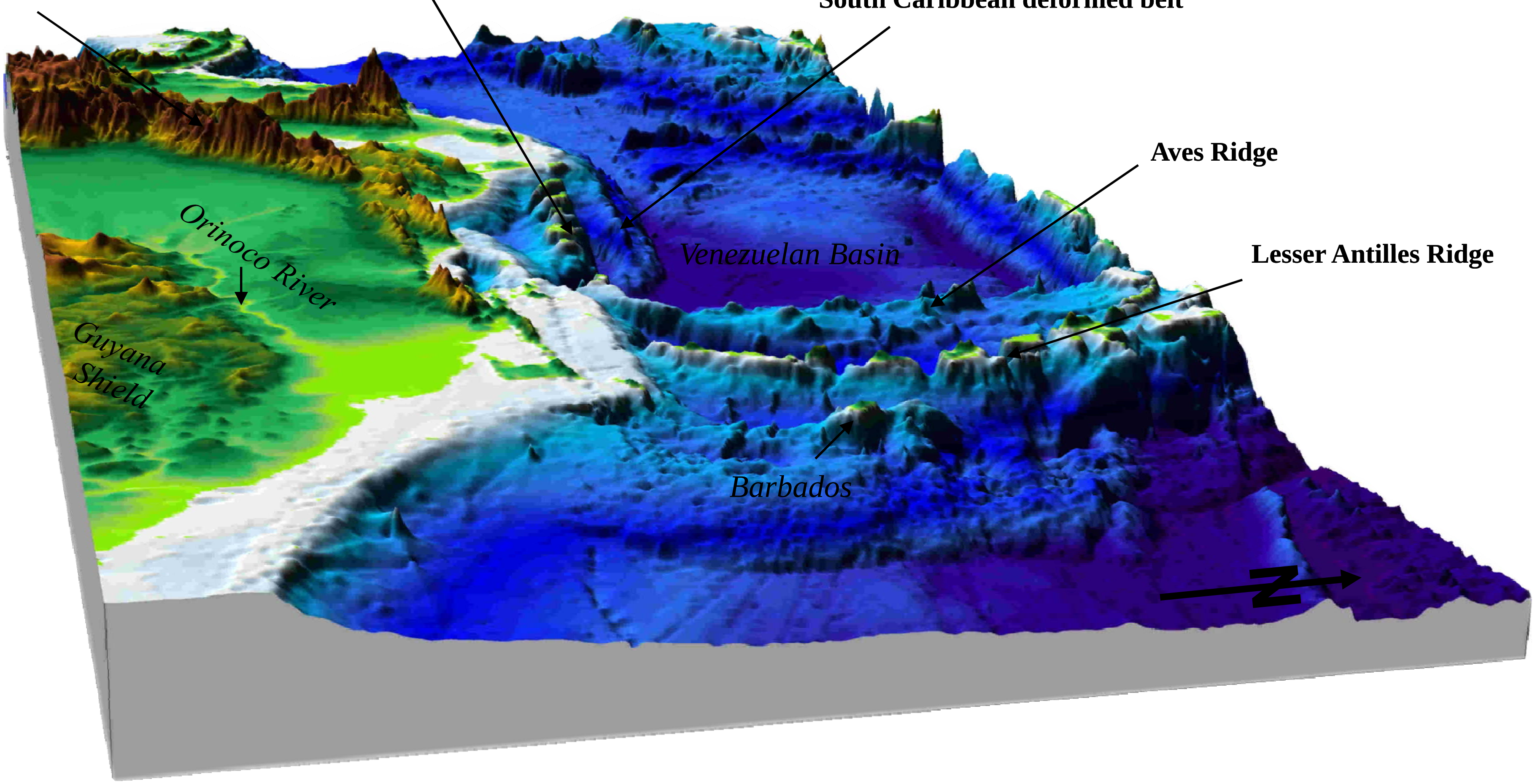
Tectonic history of Caribbean



After Lugo & Mann (2003)

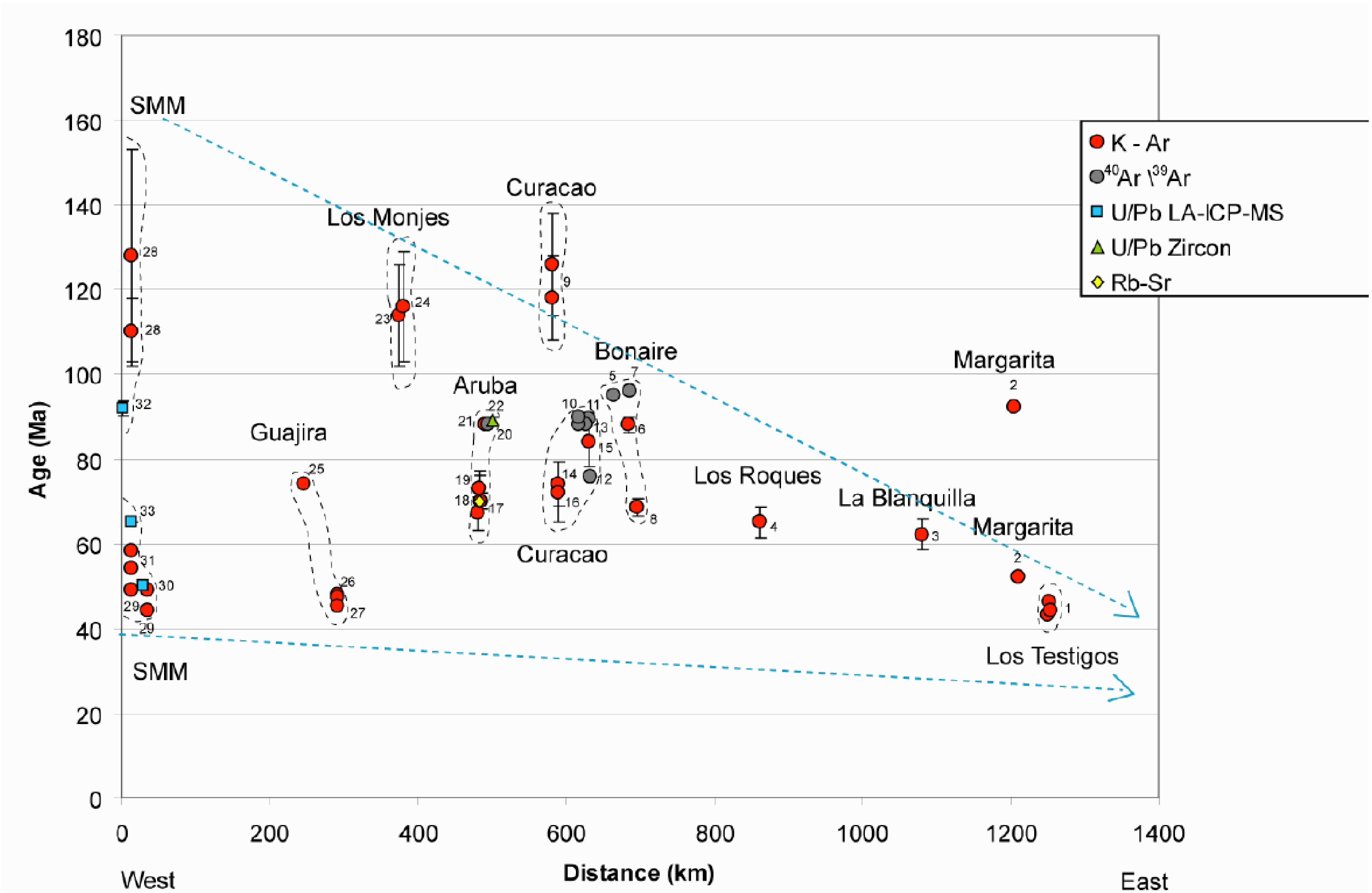
1 Late Cretaceous
2 Middle Paleocene
3 Middle Eocene
4 Middle Oligocene
5 Middle Miocene
6 Early Pliocene
7 Recent

Main morphologic features



Atlas CBTH (2009)

Younger rocks toward the east



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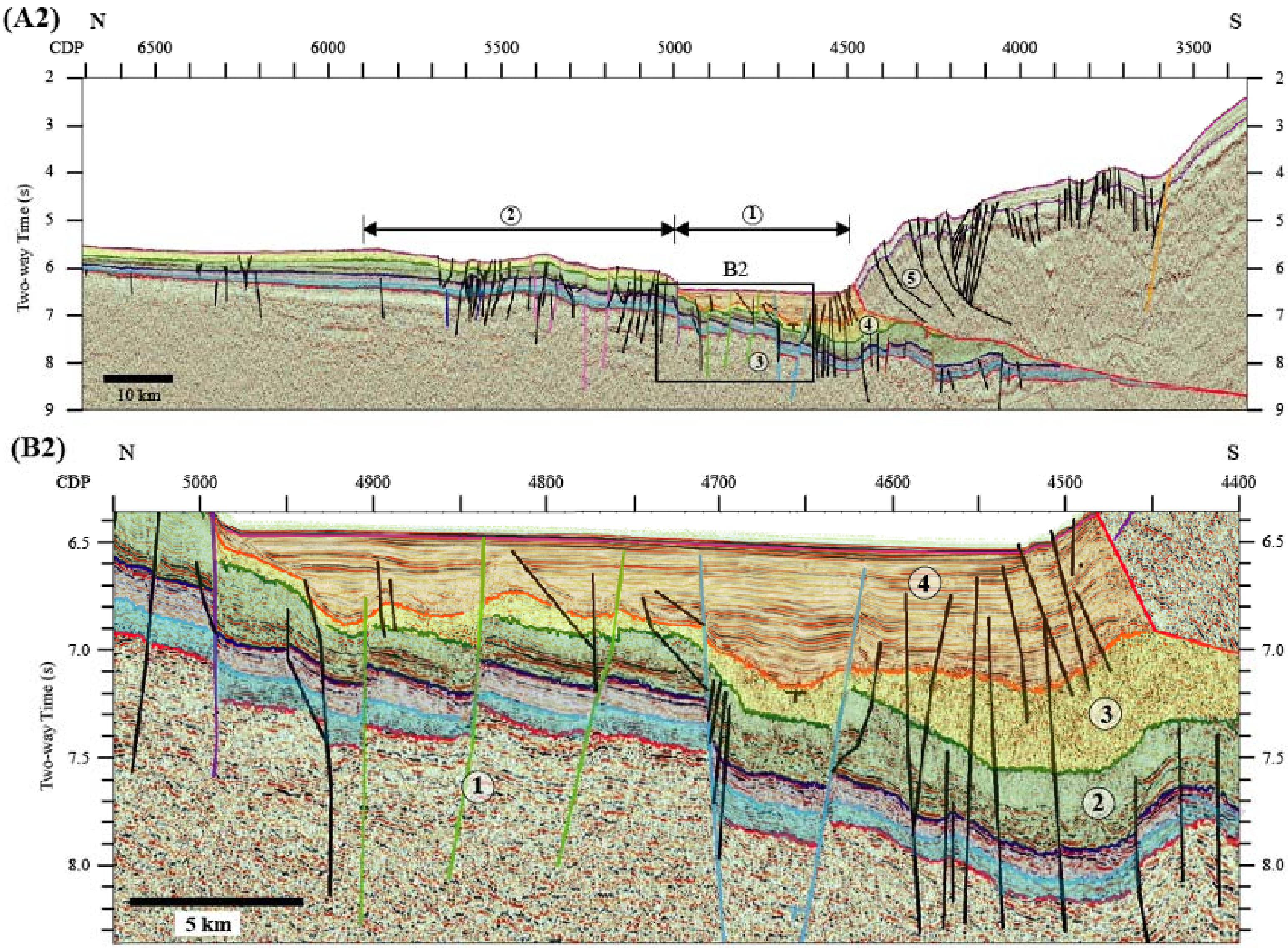
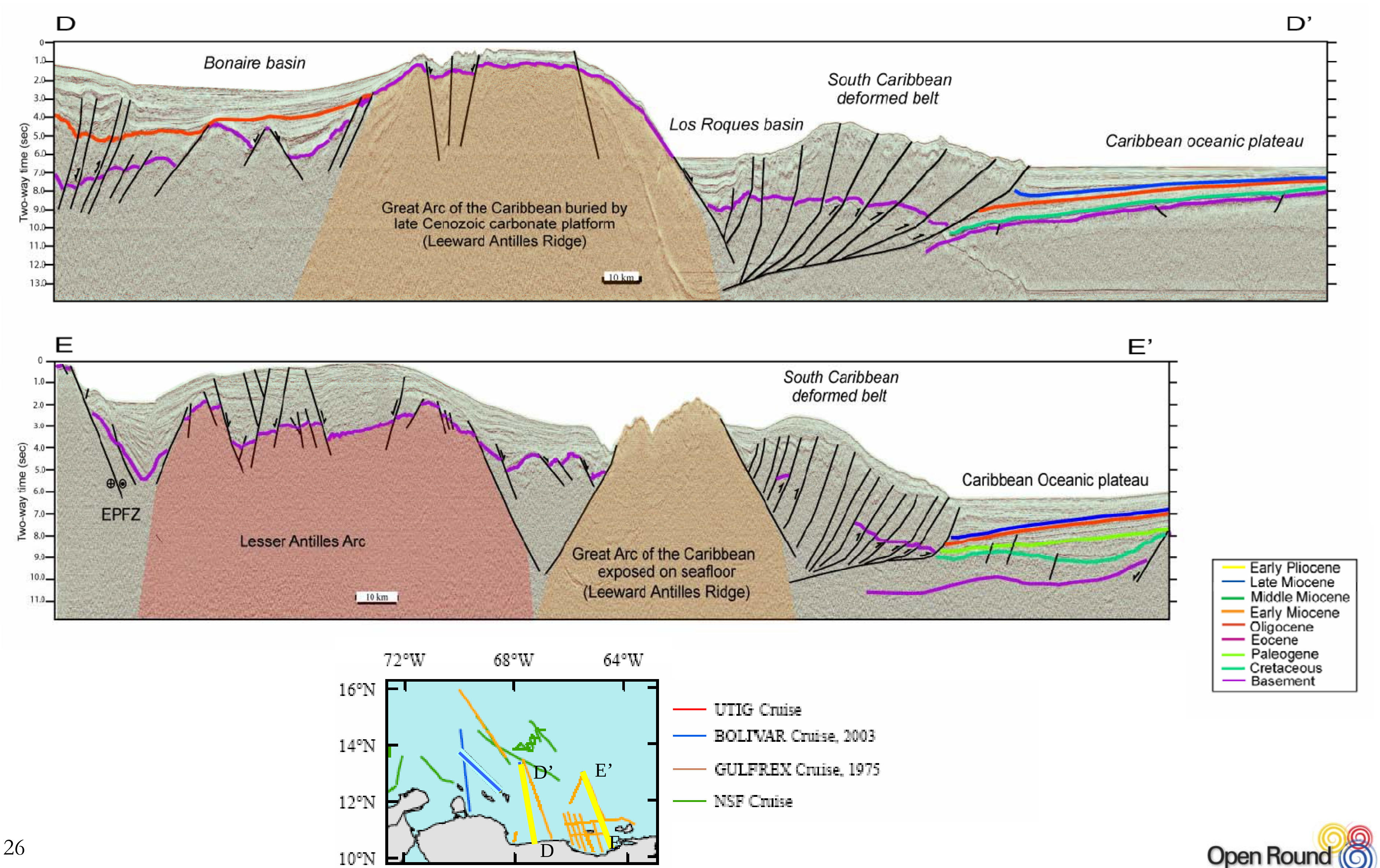
South Caribbean Deformed Belt

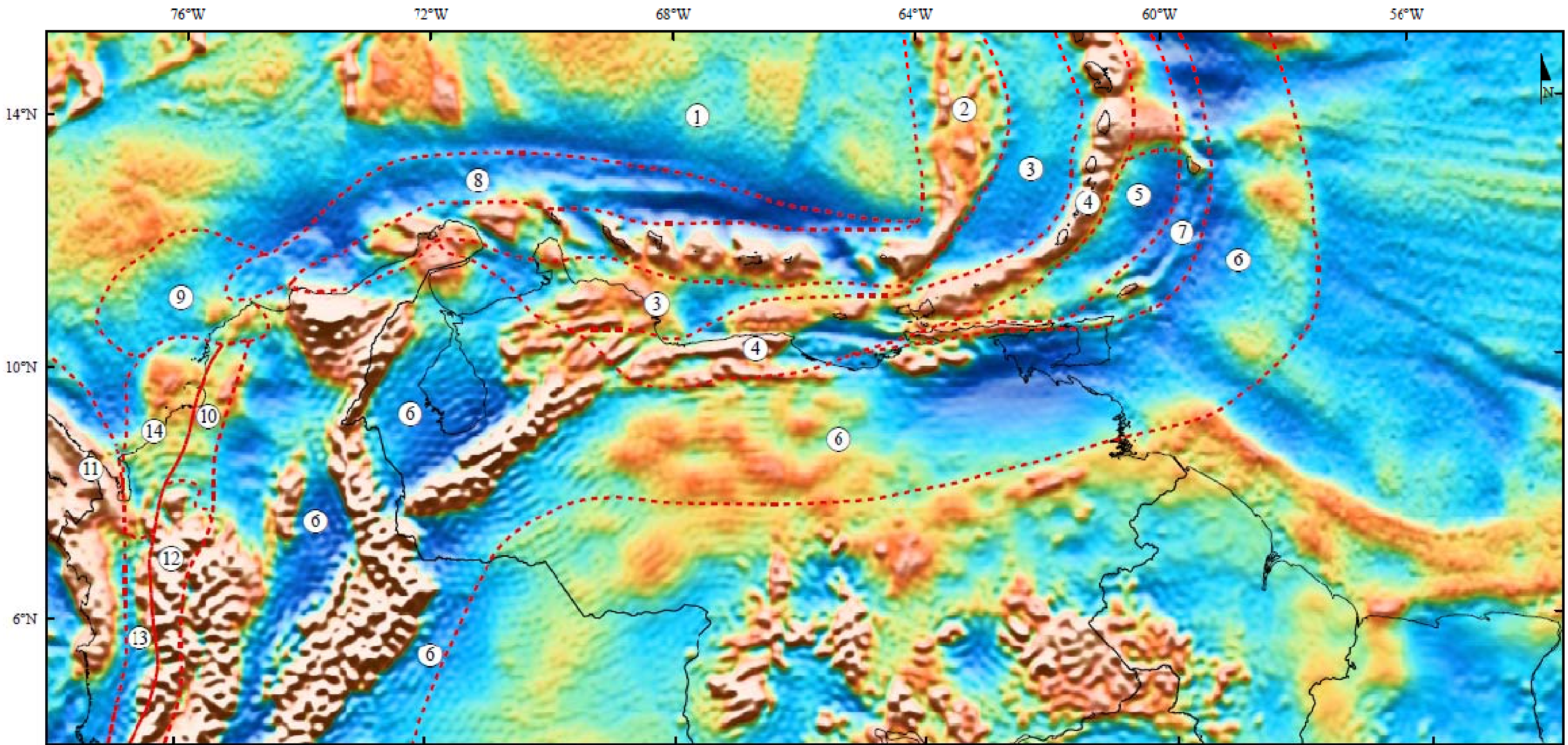


Kroehler (2007)

Evidence of the GAC



Free air anomalies



Free-air GEOSAT gravity for offshore areas and corrected free-air GEOSAT gravity for onshore areas and tectonic terranes.

1. Venezuelan basin
2. Leeward Antilles-Aves ridge island arc
3. Grenada-Bonaire-Falcon basins
4. Lesser Antilles arc-Cordillera de la Costa
5. Tobago-Carupano basins
6. Barbados accretionary prism, Eastern Venezuela, Barinas, Maracaibo, Magdalena Valley and Llanos basins
7. Barbados-Tobago ridge, Northern Range of Trinidad and Paria Peninsula
8. South Caribbean deformed belt
9. Magdalena fan
10. San Jacinto belt
11. Panama arc terrane
12. Western Cordillera
13. Atrato basin
14. Sinu belt

Tectonic terrane boundary

Free-air gravity (mgal)

-500 200

0 100 200 km

University of Texas at Austin
Institute for Geophysics
Caribbean Basins, Tectonics and Hydrocarbons, Phase II

Key reference: 126

Oil & Gas fields and seeps

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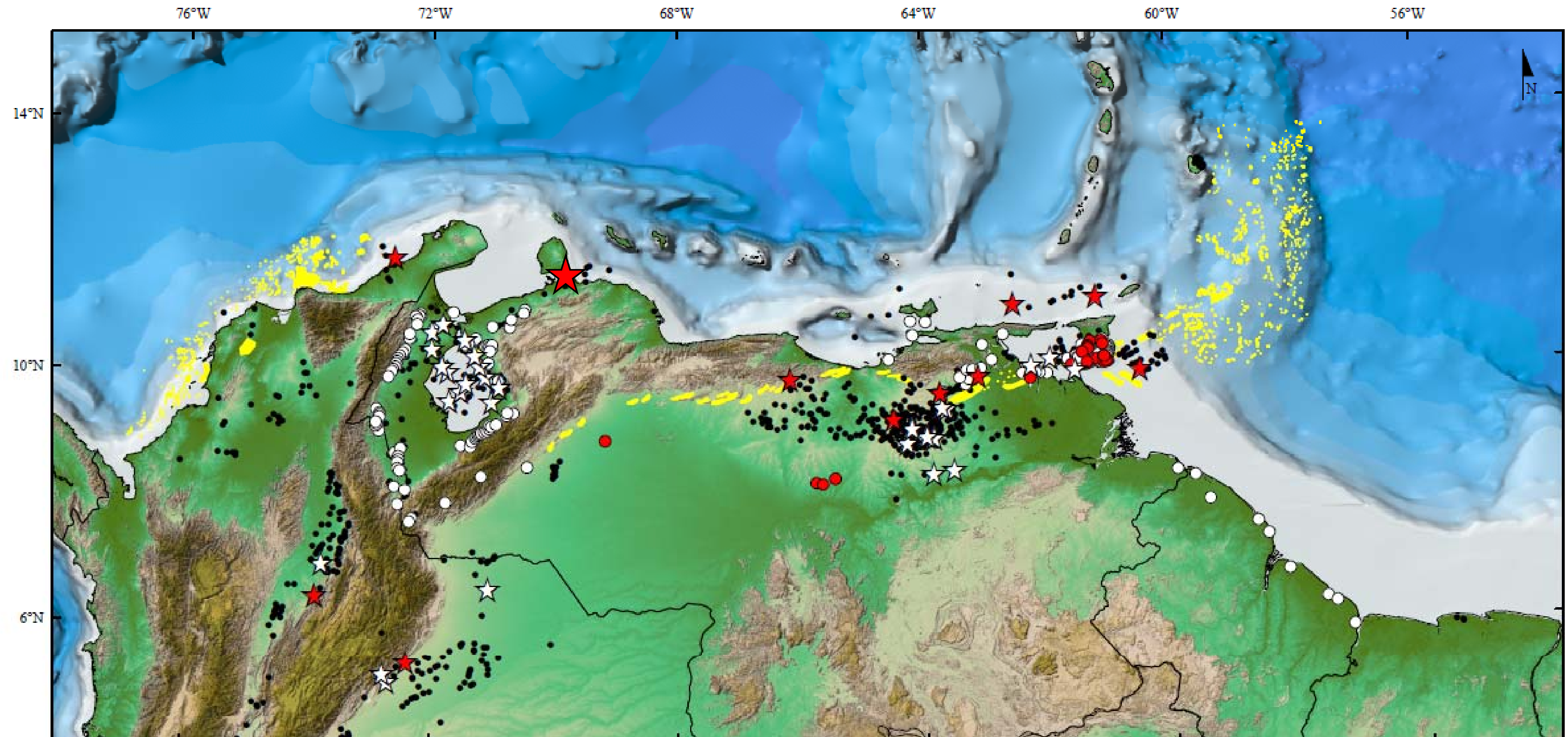


Location of giant hydrocarbon fields, natural seeps, and areas of remobilized shale. Most hydrocarbon fields are concentrated in foreland basins (Magdalena, Llanos, Maracaibo, eastern Venezuela and Columbus). The basins in this region produce approximately 4 MMBO a day and contain one of the largest hydrocarbon reserves in the world.

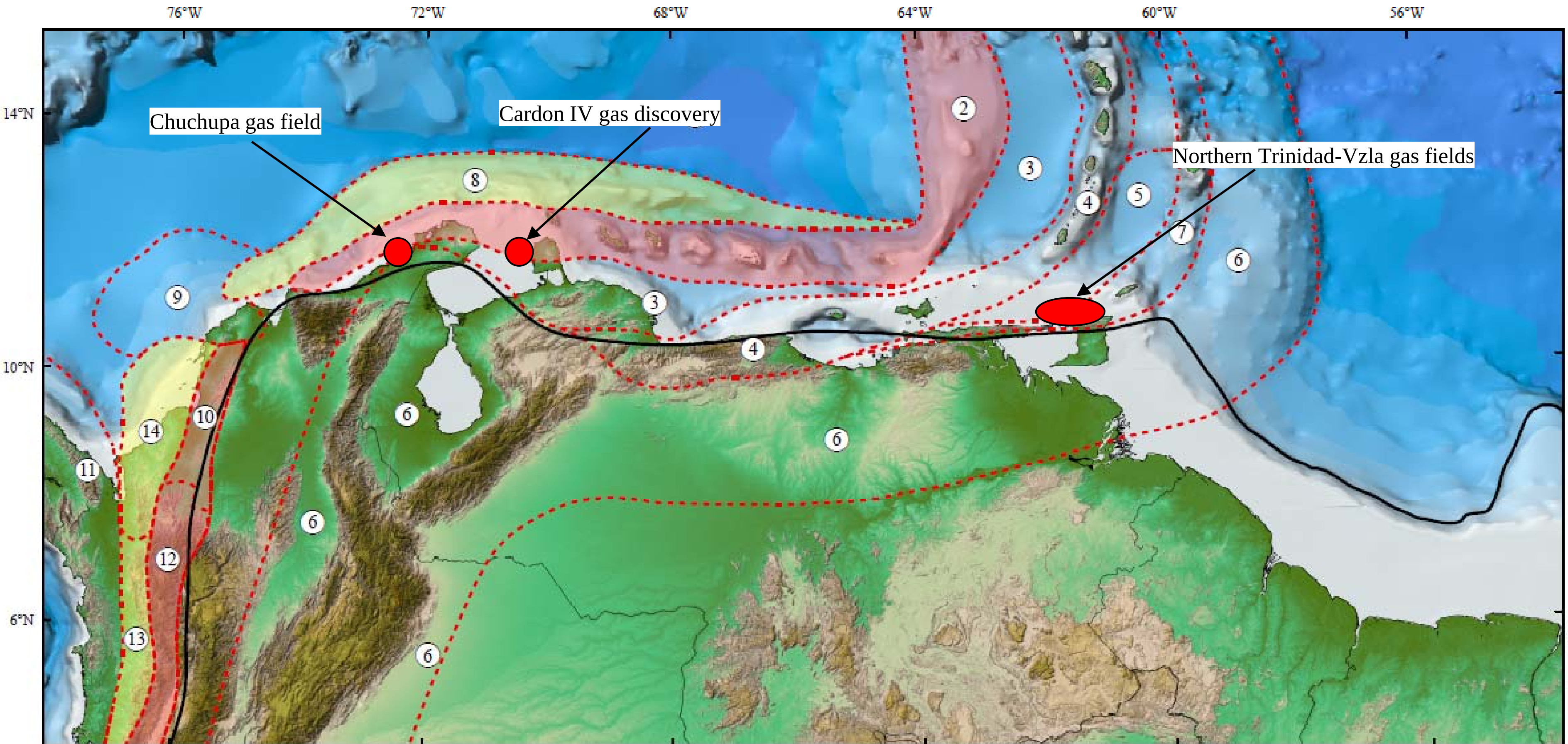
Gas giant
Oil giant
Gas seeps
Oil seeps
Oil and gas fields (undifferentiated)
Remobilized shale

0 100 200 km

University of Texas at Austin
Institute for Geophysics
Caribbean Basins, Tectonics and Hydrocarbons, Phase II

Key references: 6, 13, 28, 36, 57, 73, 82, 85, 95, 136, 142, 145, 154

Tectonic terranes and the inferred SA plate border



Tectonic belts identified in the northern South America-Caribbean margin:

1. Venezuelan basin
2. Leeward Antilles-Aves ridge island arc
3. Grenada-Bonaire-Falcon basins
4. Lesser Antilles arc-Cordillera de la Costa
5. Tobago-Carupano basins
6. Barbados accretionary prism, Eastern Venezuela, Barinas, Maracaibo, Magdalena Valley and Llanos basins
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13. Atrato basin
14. Sinu belt

Inferred edge of South American continental crust

Tectonic terrane boundary

Aves ridge - Leeward Antilles - San Jacinto belt - Western Cordillera

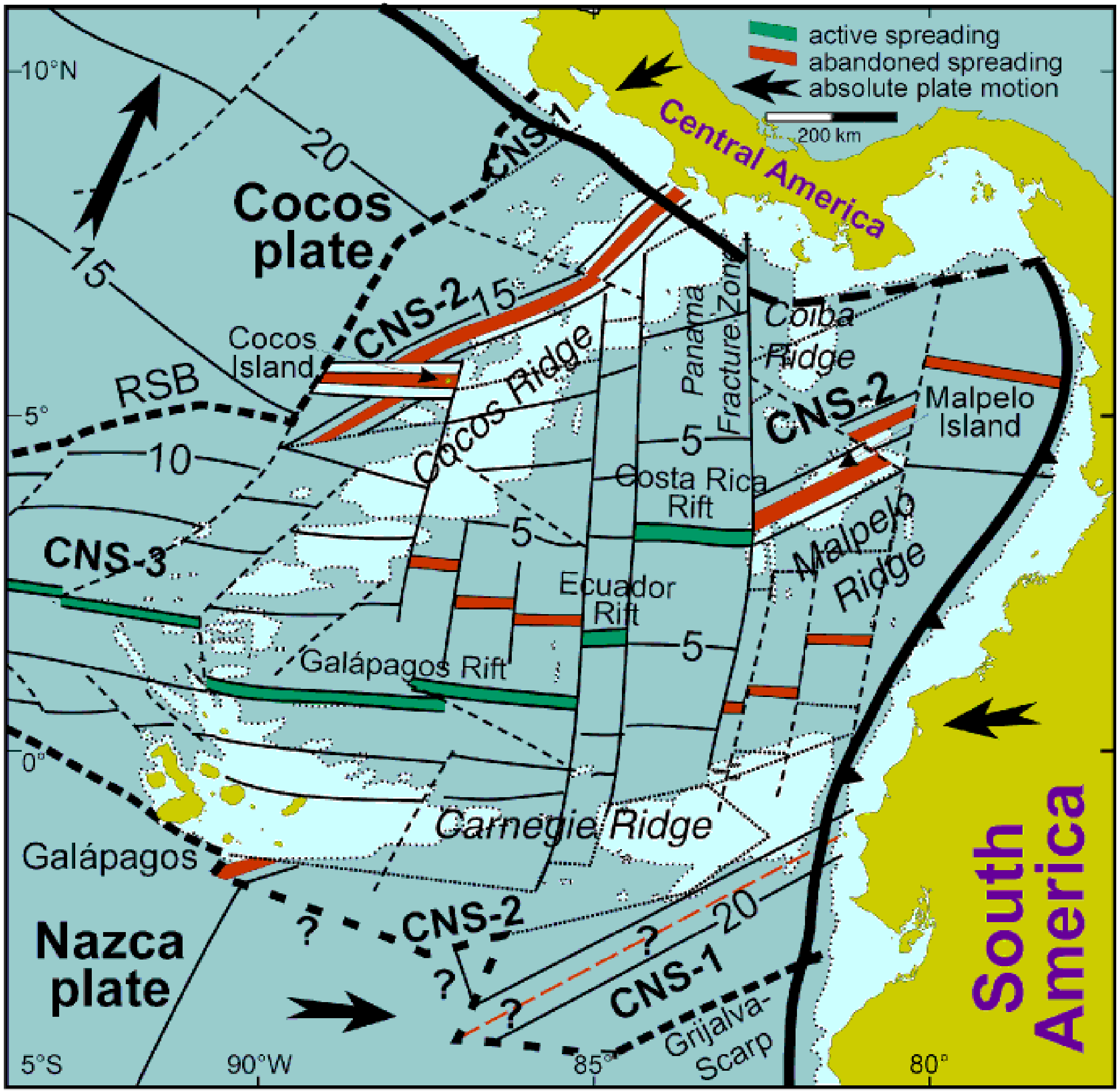
South Caribbean deformed belt

0 100 200 km

University of Texas at Austin Institute for Geophysics Caribbean Basins, Tectonics and Hydrocarbons, Phase II

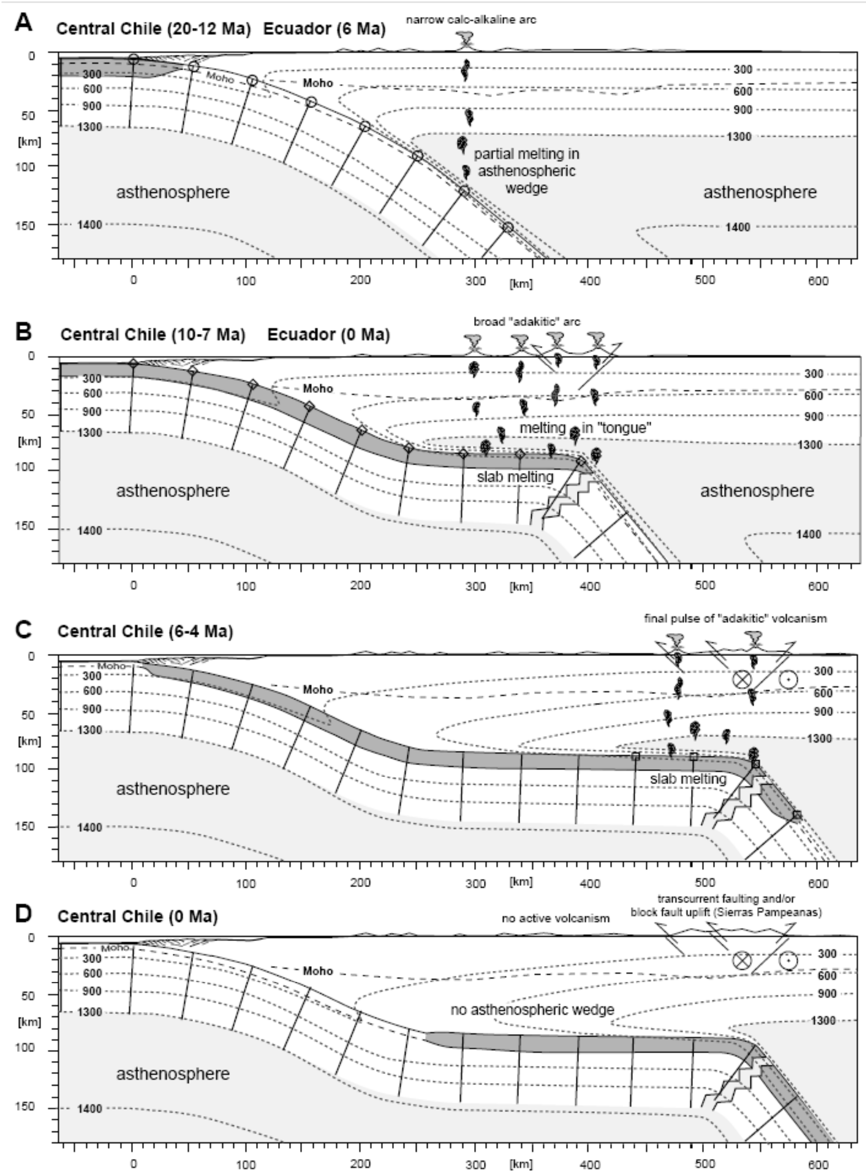
Key references: 57, 73, 147

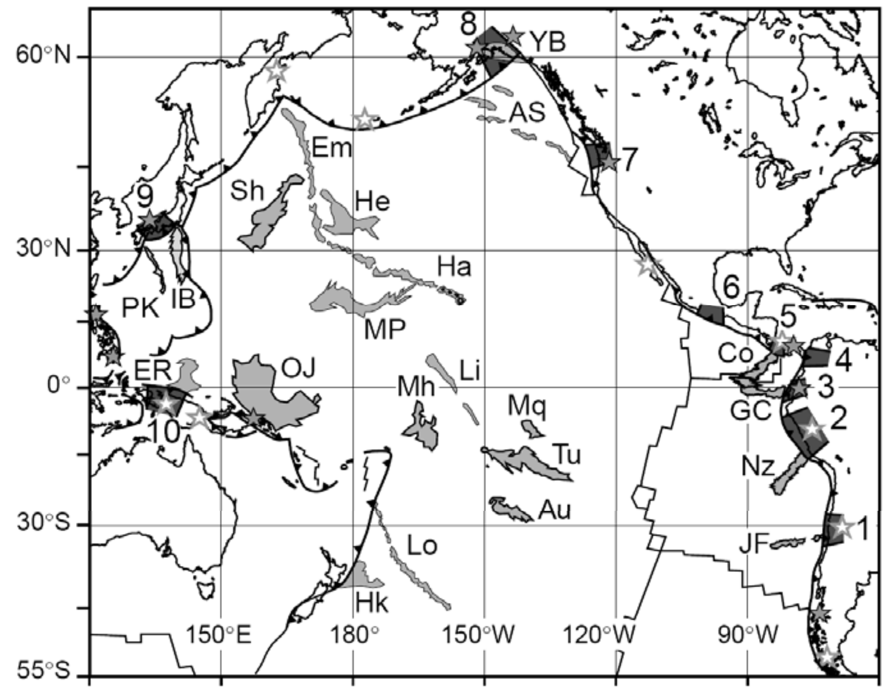
Ages and present configuration of ridges and rifts



Meschede et al. (1998)

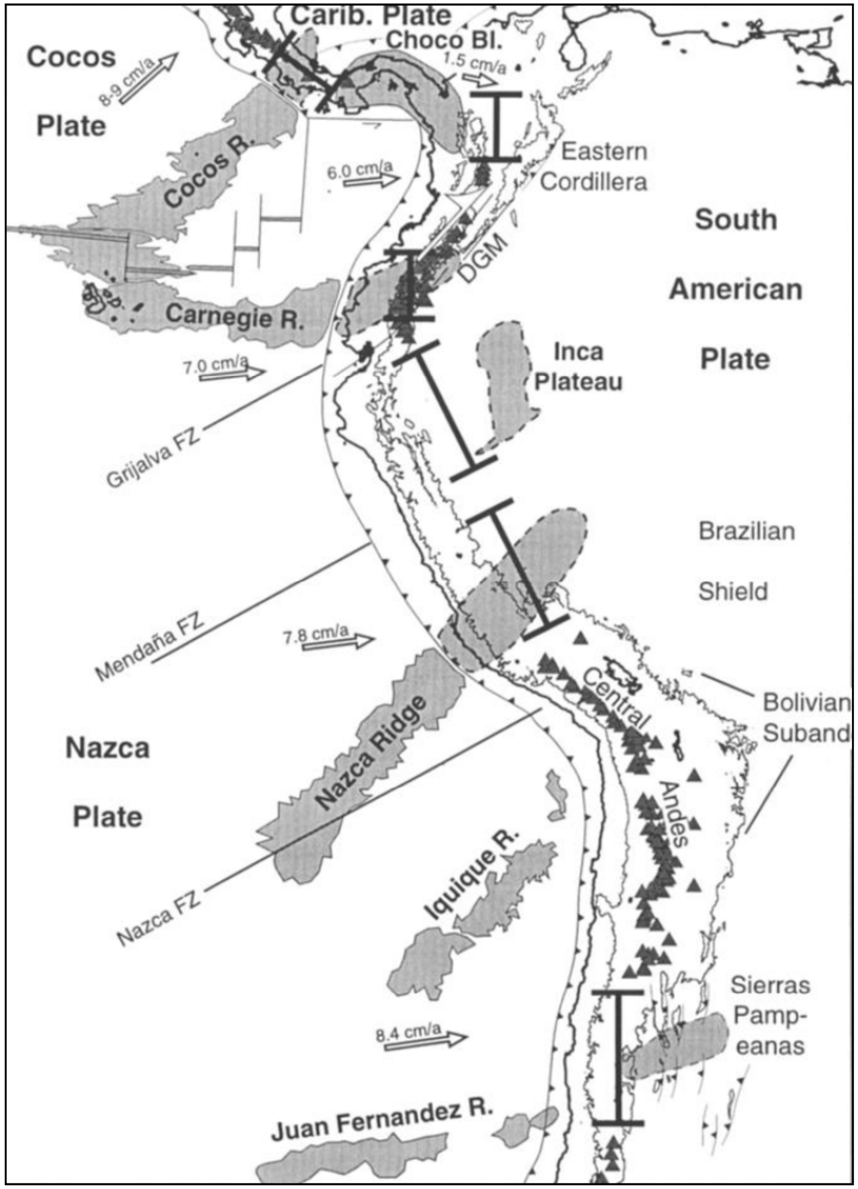
Flat subduction





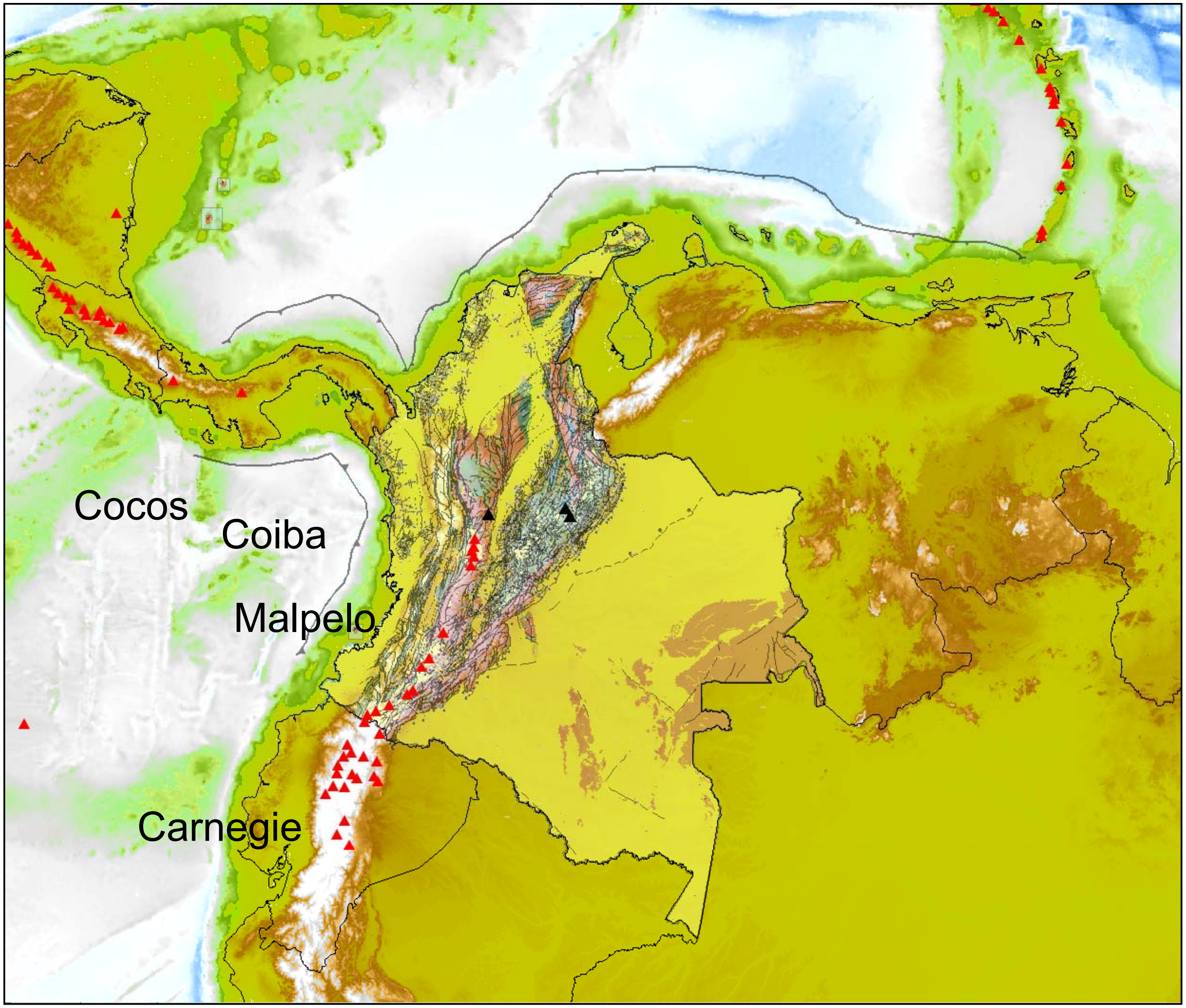
Gutscher et al. (2000)

Sunken ridges: Flat subduction

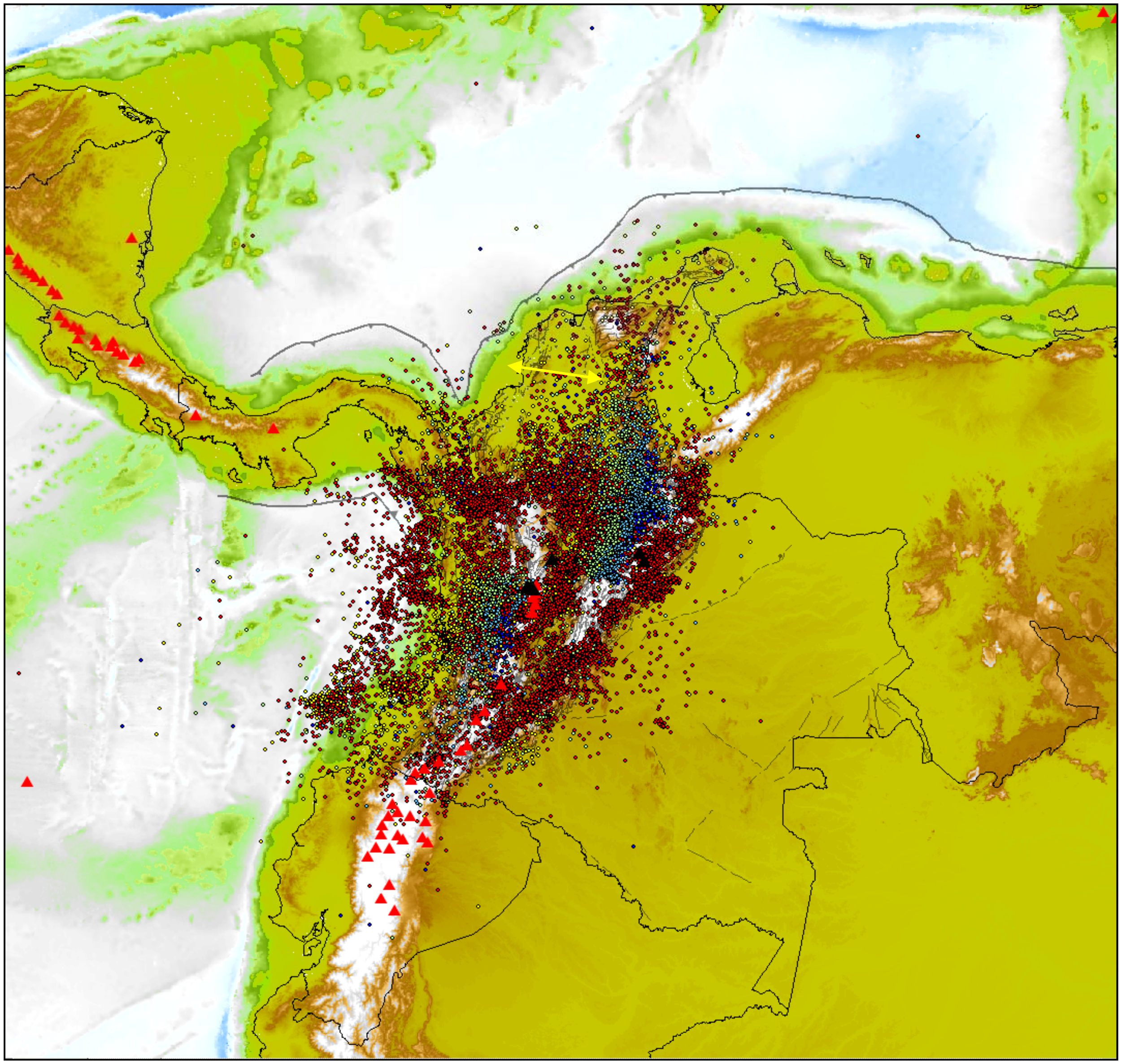


Gutscher et al. (2000)

Ridges and volcanic chains



Seismicity



The Nazca plate is subducting with evidence of tearing

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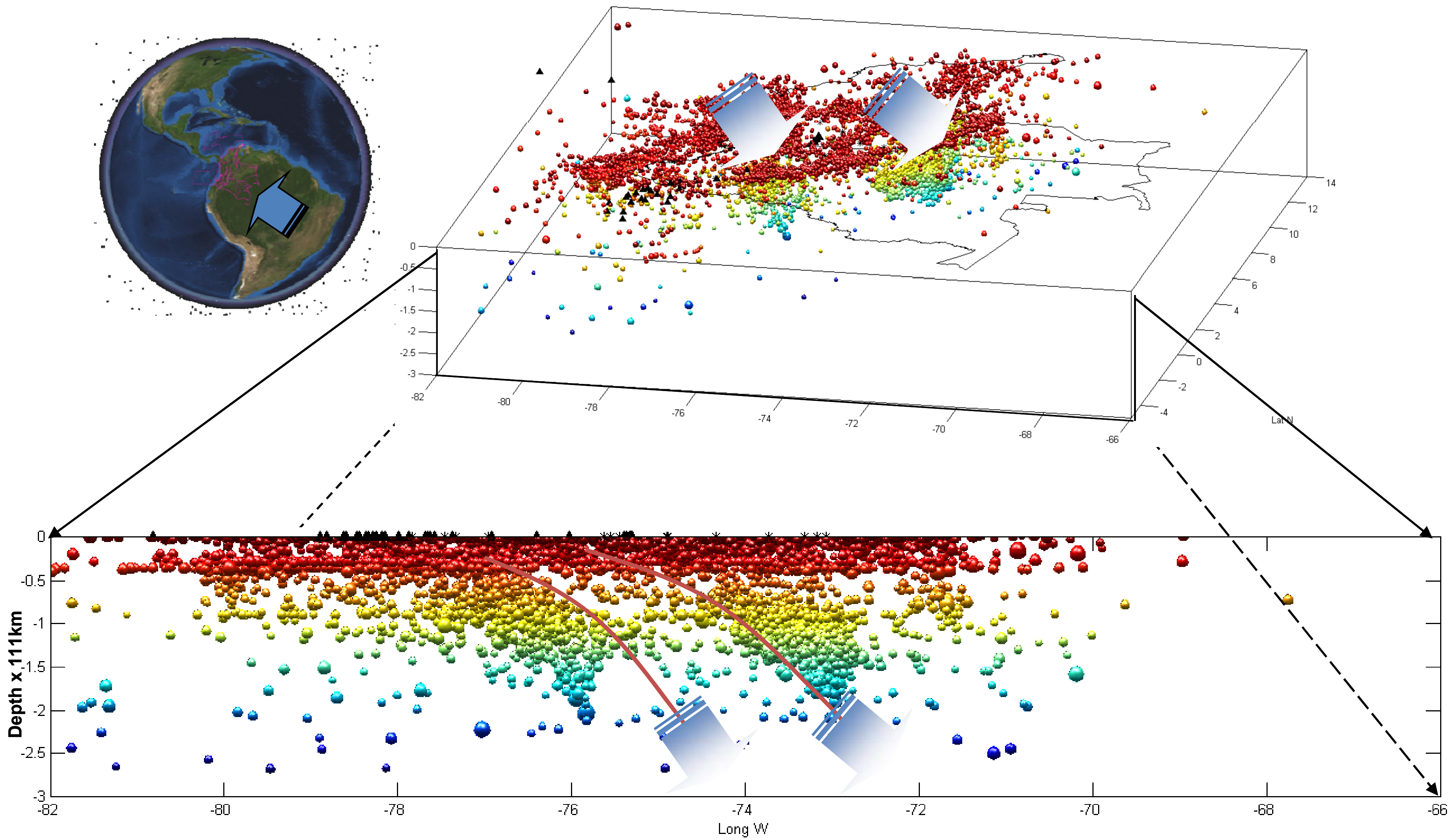

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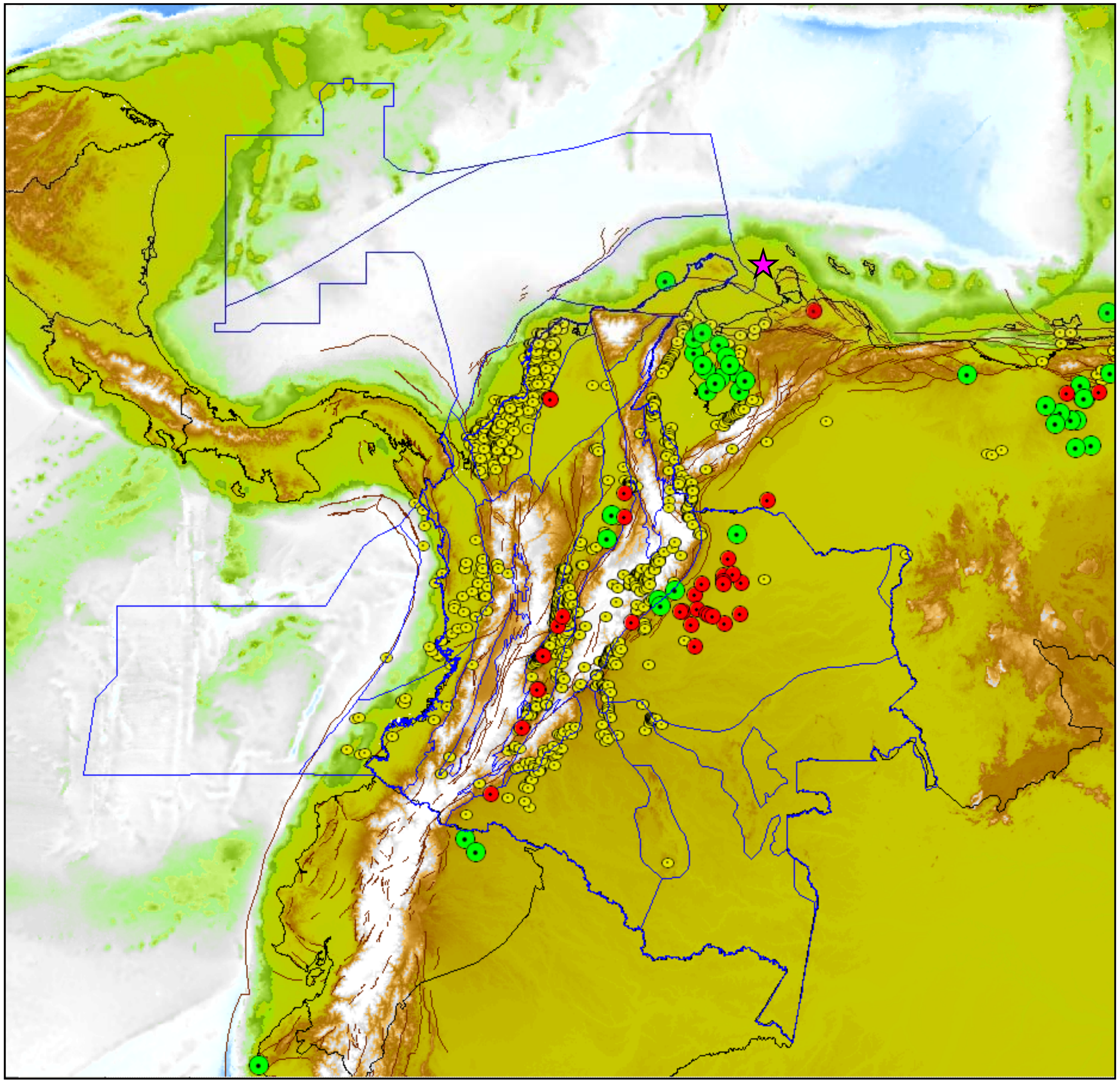
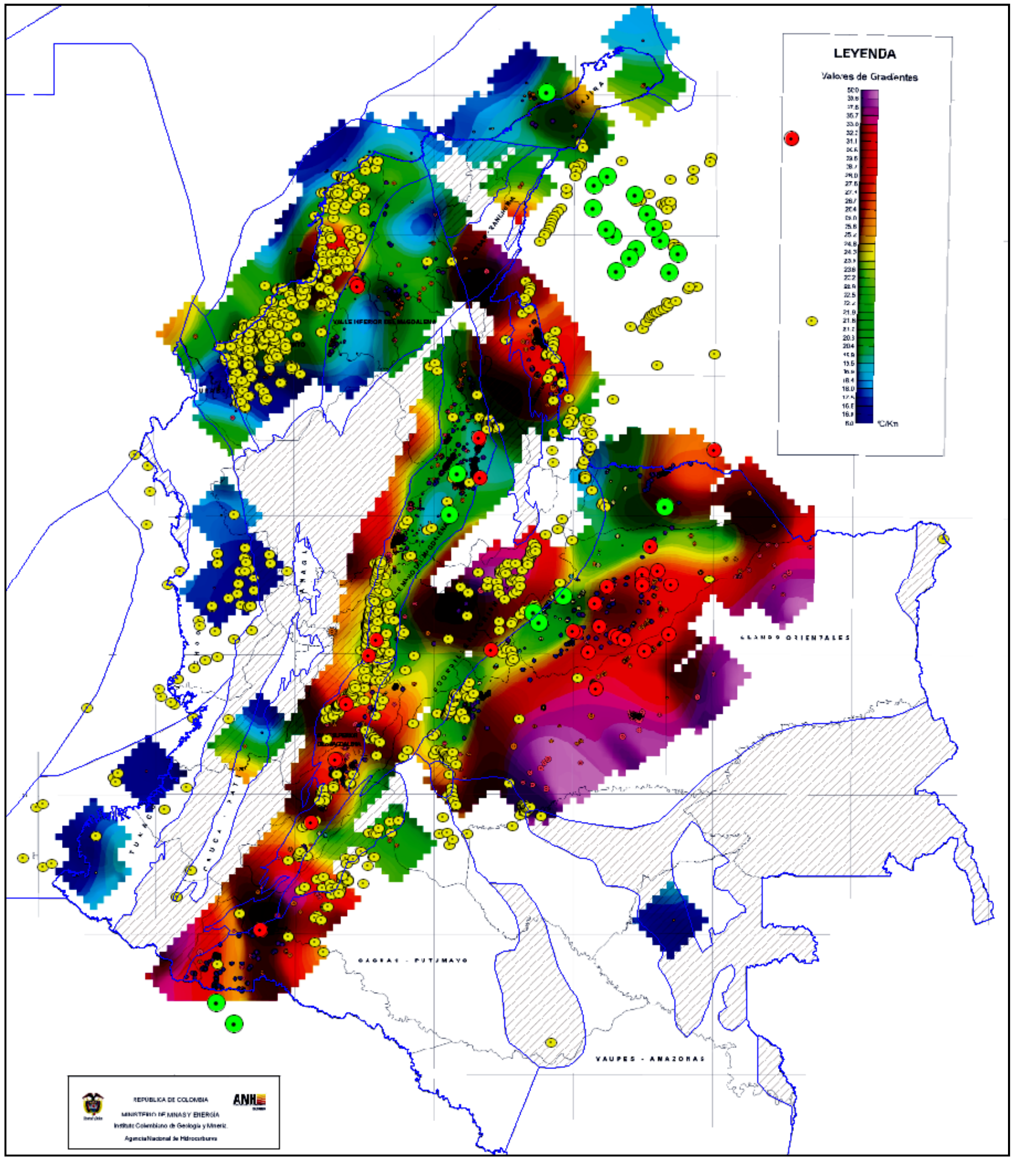
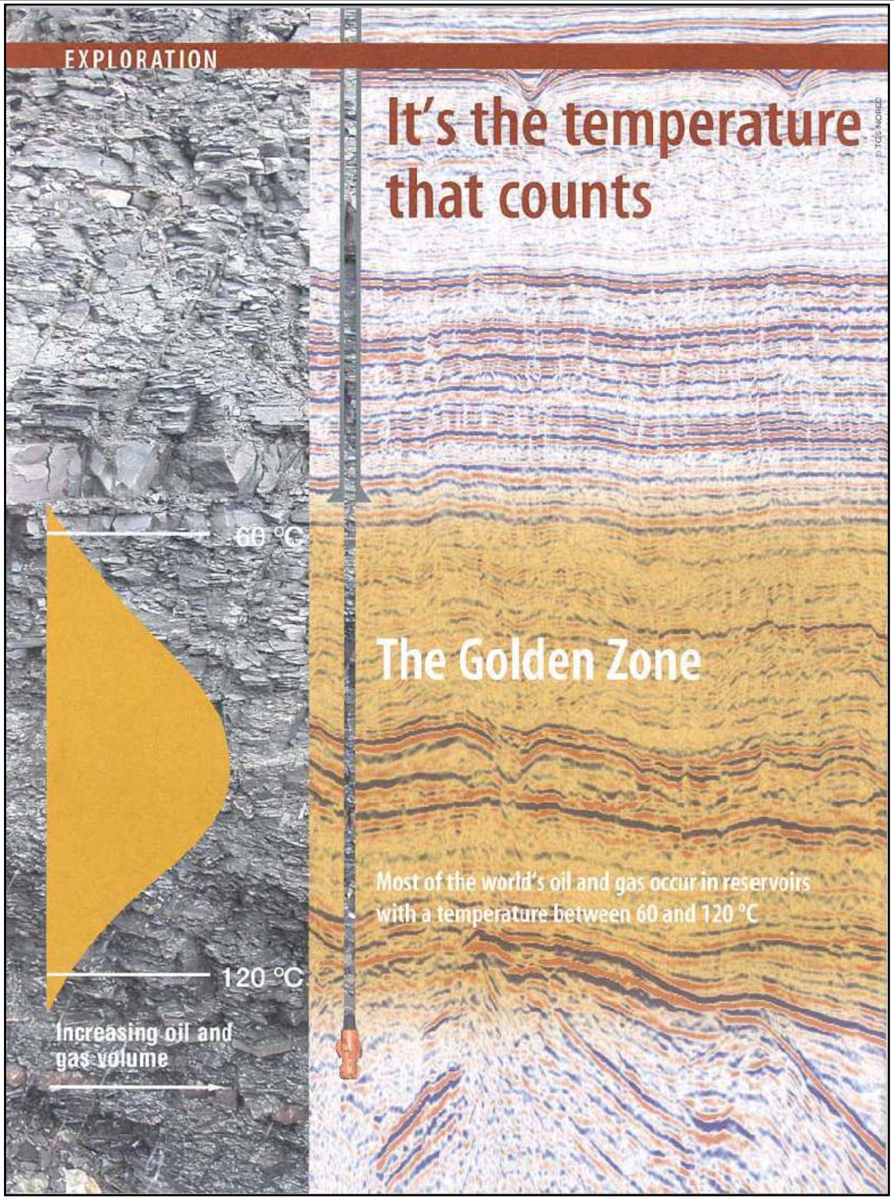
Basins and HC manifestations



Geothermal gradient and HC manifestations

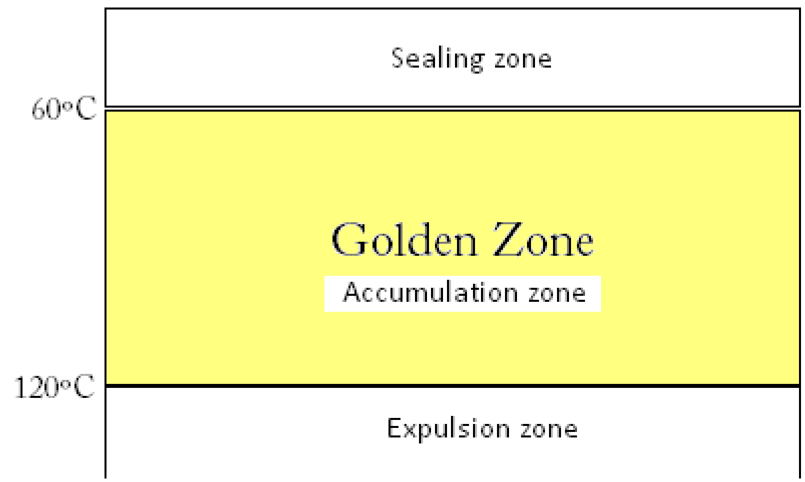


Golden zone



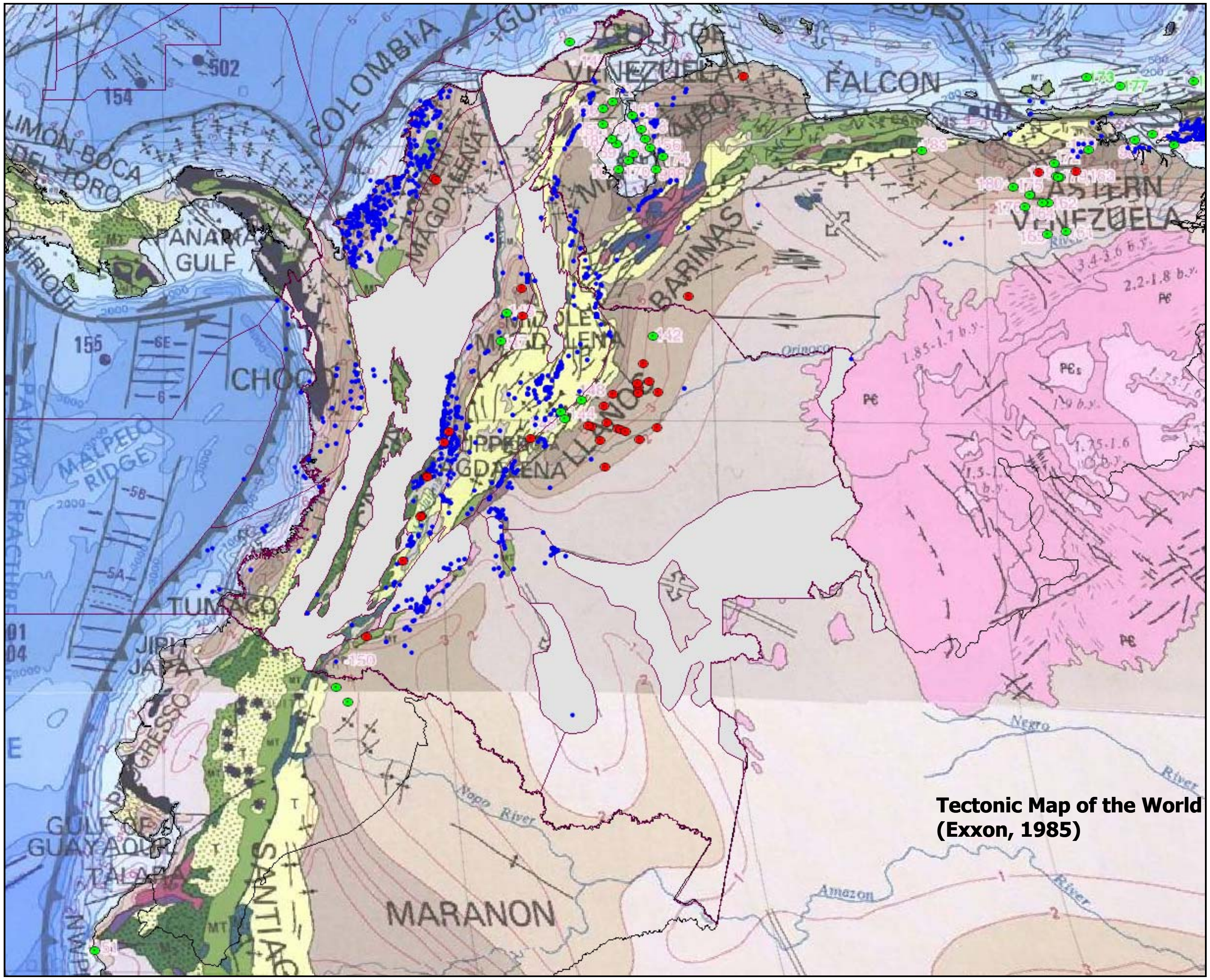
P. A. Bjorkum & P. Nadeau
STATOIL

"… the pattern in all sedimentary basins independent of the way they formed, their history of development, and age, shows an accumulation of oil and gas between 60ºC - 120ºC commonly referred to as 'The Golden Zone' ..."



Geo ExPro (September, 2004)

Depth of basement, seeps and, oil & gas fields



Tectonic Map of the World (Exxon, 1985)

Depth of basement and Golden zone

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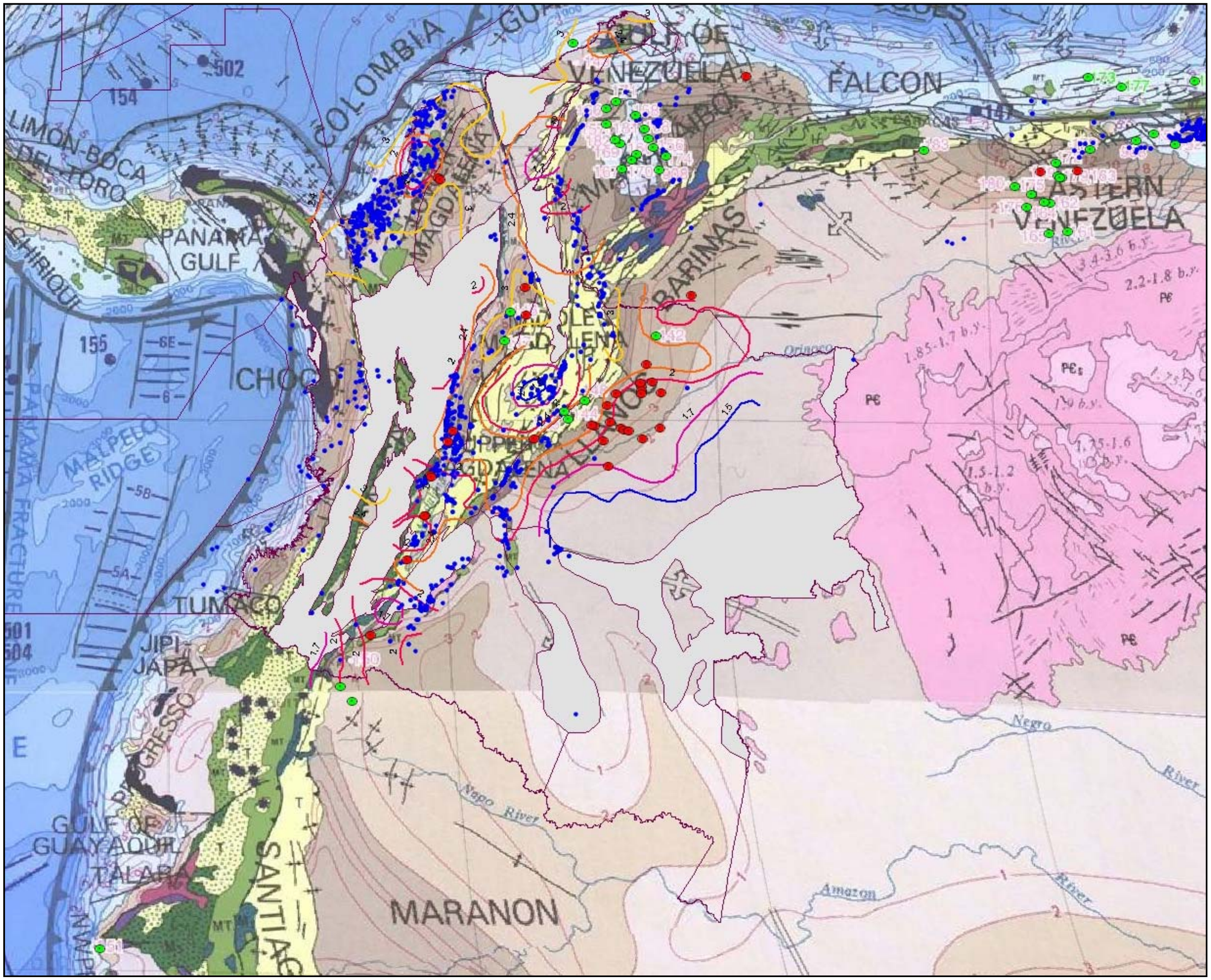

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Area of basins for estimating the potential

1. How to support with geologic evidence, the observation that production is limited to up to 6% of the total area in the Colombian basins?

   A first look at several sedimentary basins of Colombia suggests that the area assumed in the hypothesis may be greater than 6%.

2. Has there been enough HC generated for supporting the YTF expectations?

Calculation of the mass of hydrocarbons generated

Volumetric Calculation of Hydrocarbons Generated, James w. Schmoker

U.S. Geological Survey, Denver, Colorado, USA.

Magoon, L. B., and W. G. Dow, eds., 1994, The petroleum system-from source lo trap: AAPG Memoir 60.

1. The source rock is identified and its boundaries defined.

2. The mass of organic carbon in the source rock is calculated.

$$M(gTOC) = [TOC\ (wt\ \%)/100)\ x\ r\ (g/0113)\ x\ V\ (cm^3)$$

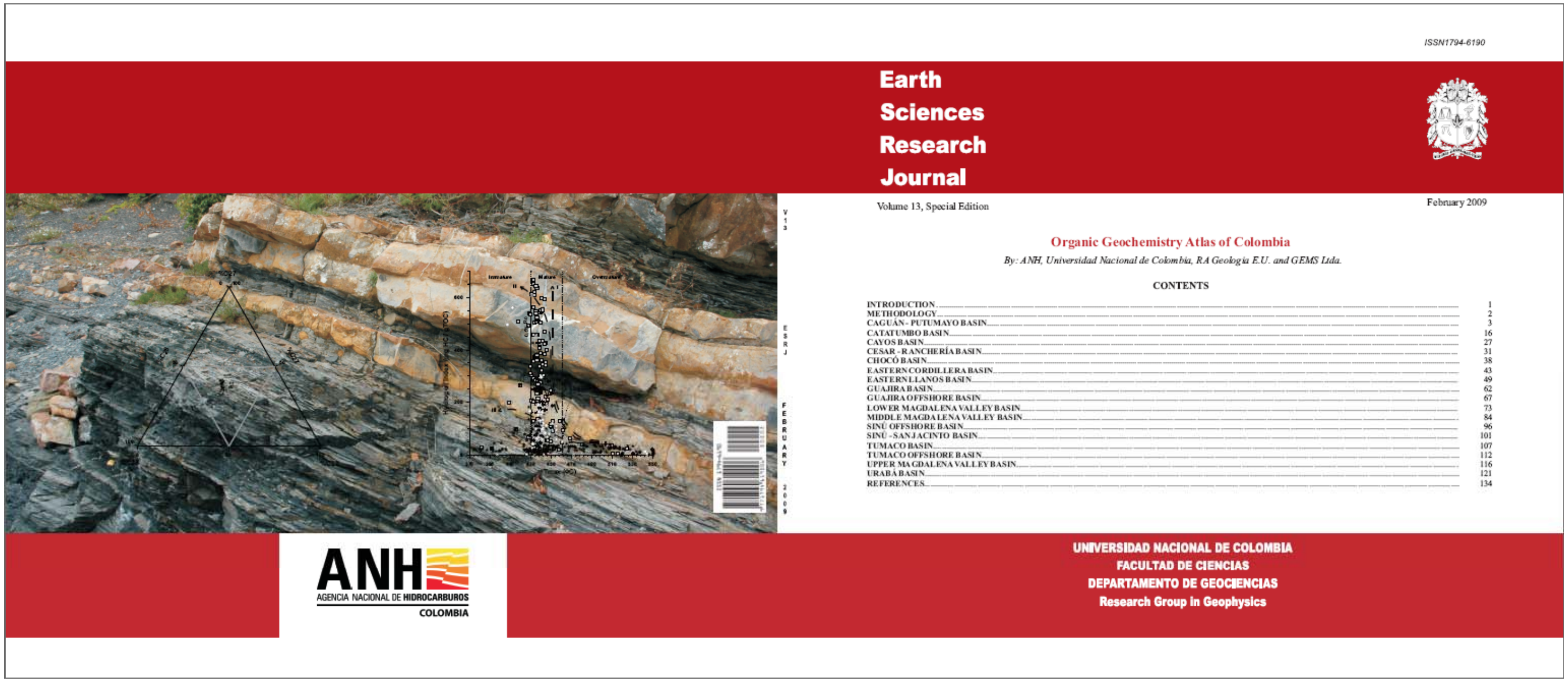
3. The mass of hydrocarbons generated per unit mass of organic carbon is estimated.

$$R(mgHC/gTOC) = HIo\ (mg\ HC/g\ TOC) - HIp\ (mg\ HC/g\ TOC)$$

4. The total mass of hydrocarbons generated is determined by multiplication of this data.

$$HCG(kgHC) = R(mg\ HC/g\ TOC)\ x\ M\ (g\ TOC)\ X\ 10^{-6}\ (kg/mg)$$

Uncertainties and other basins? : Montecarlo



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Organic Geochemistry Atlas of Colombia

By: ANH, Universidad Nacional de Colombia, RA Geología E.U. and GEMS Ltda.

CONTENTS

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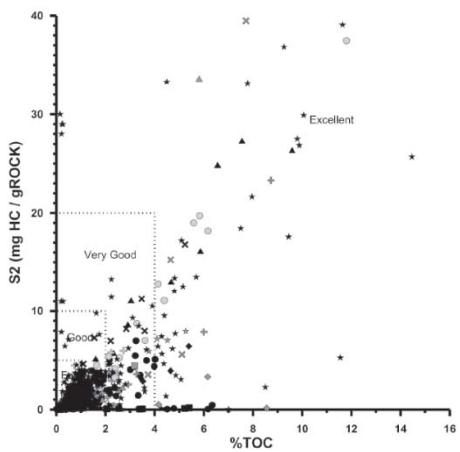
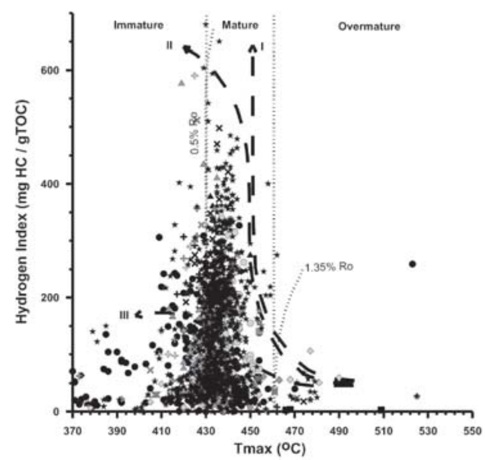
AGENCIA NACIONAL DE HIDROCARBUROS
COLOMBIA

UNIVERSIDAD NACIONAL DE COLOMBIA
FACULTAD DE CIENCIAS
DEPARTAMENTO DE GEOCIENCIAS
Research Group in Geophysics





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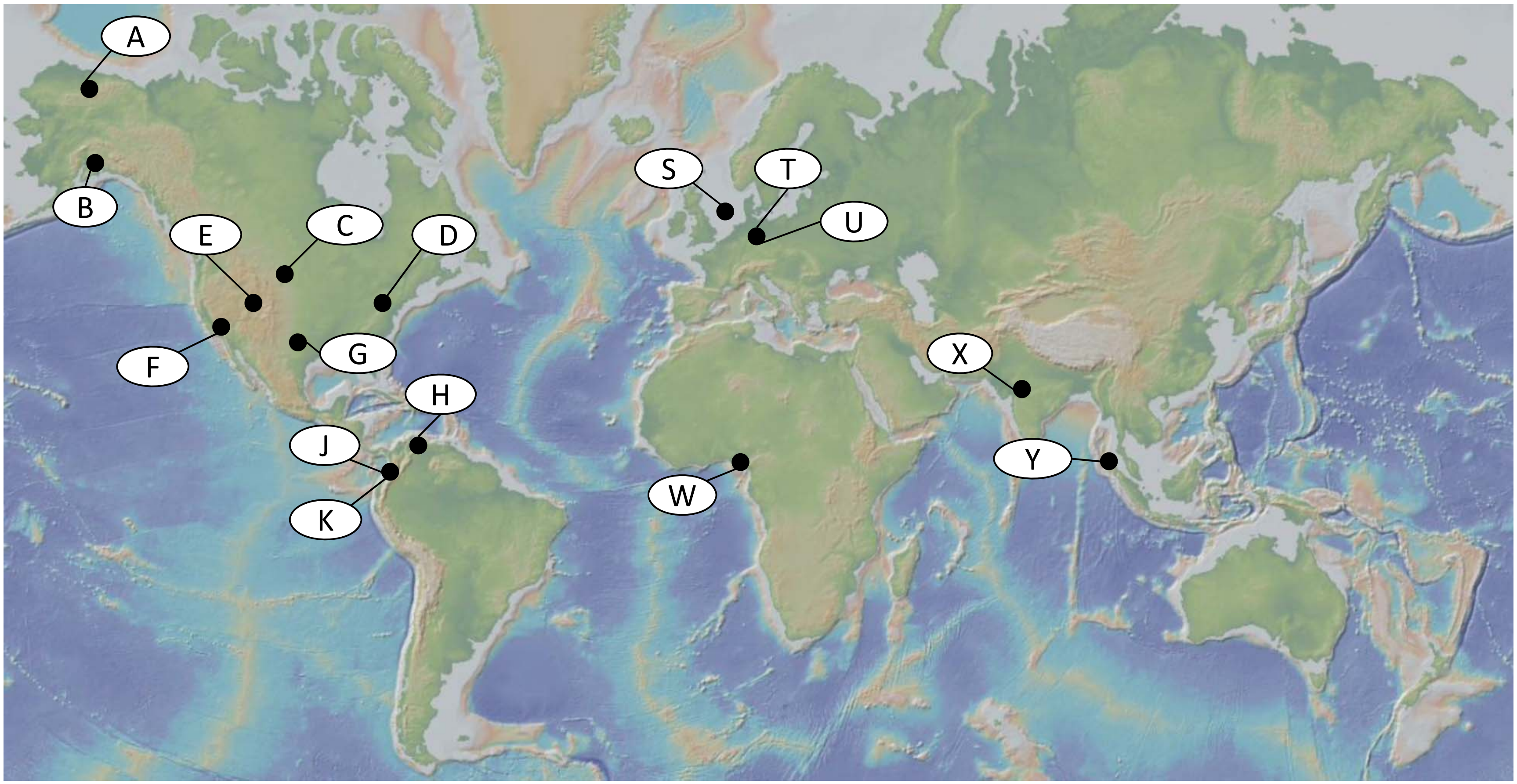
Case studies



Magoon, L. B., and W. G. Dow, eds., 1994, The petroleum system-from source lo trap: AAPG Memoir 60.

Values from case-studies used to calculate the amount of generated petroleum from pods of Active Source Rock

Map Symbol	Petroleum System	TOC (wt%)	ρ (g/cm³)	A (10^{12} cm²)	h (10^2cm)	v (10^{15}cm³)	M (10^{12}g TOC)	HIo (°)	HIo (°)	R (°)	HCG (10^9kg)
A	Ellesmerian (!)	3,5	2,4	900	160	14.400	-	-	-	-	-
A		2	2,4	1100	800	88.000	5.433.600	-	-	200	1.086.720
B	Tuxedni - Hemlock(!)	1,7	2,6	15	1000	1.500	66.800	300	100	200	13.400
C	Heath - Tyler (!)	2,5	2,3	400	30	1.200	69.000	600	300	300	20.700
D	Point Pleasant - Brassfield (!)	6	2,3	21	200	420	58.000	800	350	450	26.100
E	Green River (!)	6	2,3	21	200	420	58.000	800	350	450	26.100
F	Soda Lake - Painted Rock (!)	2,1	2,4	2,6	300	76	3.990	600	200	400	1.596
G	Simpson - Ellemburger (.)	1,7	2,5	96	35	336	14.600	425	150	275	4.020
H	La Luna - Misoa (!)	5,6	2,7	475	65	3.090	4.550	650	100	550	250.000
J	Villeta - Monserrate (!)	1,8	2,5	9	135	122	-	430	250	180	-
J		2,5	2,5	9	100	90	11.000	725	425	300	2.640
K	Villeta - Caballos (!)	1,8	2,5	7,5	135	101	-	430	250	180	-
K		2,5	2,5	7,5	100	75	9.120	725	425	300	2197
S	Mandal - Ekolisk (!)	6,7	2,5	11,5	1250	-	-	-	-	-	-
S		6,7	2,5	26,5	750	-	-	-	-	-	-
S		6,7	2,5	74,8	250	1.210	666	-	-	650	66.600
T	LSB Jurassic (!)	8	2,3	49,6	25	124	22.820	-	-	300	6.850
U	LSB Lower Cretaceous (!)	4,5	2,3	27,3	25	68	7.064	-	-	370	2.600
W	Akata - Agbada (!)	2,2	2,6	76,8	2310	17.700	1.012.000	232	161	71	71.850
X	Cambay - Hazad (!)	2,6	2,6	54,1	750	4.058	272.000	121	93	28	7610
Y	Bampo - Peutu	0,9	2,6	76	345	2.620	-	200	100	100	-
Y		0,7	2,7	76	460	3.500	127.100	200	70	130	14.800

Magoon, L. B., and W. G. Dow, eds., 1994, The petroleum system-from source lo trap: AAPG Memoir 60.

Direct geochemical observations of 16 basins

ANH

Caguán - Putumayo

ACAE-1	LINDA-1
ACAE-10	LUCILLE-1
ALEA-1	MANDUR-3
AZUL GRANDE-2	MANDUR-5
BAGRE WEST-1	MIRAFLOR-1
BURDINE-1	NANCY-1
CAFELINA-1	ORITO SUR-1
CAIMAN-2	ORITO-20
CAIMAN-4	ORITO-80
CALDERO-1	PAYARA-1
CARIBE-1	PINUNA-1
CARIBE-4	PUTUMAYO-1
CENCELLA-1	QUILILI-1
CHIGUACO-1	QUILLACINGA-1
CONDOR-1	QUILLACINGA-2
CONEJO-1	RIO MOCOA-1
EVELYN-1	RIO PESCADO-1
GARZA-1	SUCUMBIO-2
GAVILAN WEST-1	TAPIR-1
GAVILAN WEST-2	TEMBLON-1
GAVILAN-1A	TOROYACO-1
GUAMUES-1	UMBRIA-1
HORMIGA-1	URIBE-1
HORMIGA-1X	VENADO-1
LA TURBIA-1	YURILLA-1

Tumaco offshore

SANDI-1

Catatumbo

CARBONERA-4K
CARBONERA-5K
CERRITO-1
CERRO GORDO-3
ESLABONES-1
ESPERANZA-3
MUCURERA-3
PETROLEA-91
RIO DE ORO-14
RIO DE ORO-14K
RIO ZULIA-14
SARDINATA-1
SARDINATA-3K
SARDINATA-3K
SARDINATA NORTE-2
TIBU-178K
TIBÚ-182
TIBU-2K
TIBU-408K
TIBU-87
TIBU-87 (VETA-1)
TIBU-91K

Guajira offshore

MERO-1
SAN JOSE-1

Eastern Cordillera

ALPUJARRA-1
APICALA-1
CHITASUGA-1
CORMICHOQUE-1
CORRALES-1
SUESCA NORTE-1
TAMAUKA-1
VILLA RICA-1

Sinu offshore

BARRANQUILLA-1
CARTAGENA-2
CARTAGENA-3
CIENAGA-1
SAN DIEGO-1

Chocó

BUCHADO-1

Cesar - Rancheria

Cesar F-1X
COMPAE-1
EL PASO-3
MOLINO 1-X

Sinu – San Jacinto

BALSAMO-2
CARACOLI-1
CHINU-1
LA YE-1
LORICA-1
MOLINERO-1
MOLINERO-2
PARUMAS-1
POLONUEVO-1
ARROYO GRANDE-1
PALONUEVO 105-1
PORQUERA-1
SAN ANDRES A-1
SANTA RITA-1
TOLU-1

Urabá

NECOCLI-1

Tumaco

MAJAGUA-1

Los Cayos

PERLAS-3

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TOC, HI, Tmax of 257 wells

Eastern Llanos

ALMAGRO-1	LOS TEQUES-1
ANACONDA-1	LUNA ROJA-1
APIAY-2	MARE MARE-1
APIAY-3	MEDINA-1
APIAY-4P	MORICHAL-1
ARAUCA-1	MORICHITO-1
ARAUQUITA-1	NEGRITOS-1
BUENOS AIRES X-14	PARAVARE-1
CANDILEJAS-1	POMARROSO-1
CANO CUMARE-1	PORE-1
CANO DUYA-1	PUERTO RICO-1
CANO LIMON-1	QUENANE-1
CANO VERDE-1	1127-1X
CASANARE-1	RANCHO HERMOSO-1
CHAFURRAY-5	RIO ELE-1
CHAPARRAL-1	RONDON-1
CHAVIVA-1	STRAT-XR-11A
CHIGUIRO-1	X-R-859
COPORO-1	S-11A
COROCITO-1A	SA-1
COROZAL-1	SA-11
CUMARAL-1AX	SAN JOAQUIN-1
EL MORRO-1	SAN PEDRO-1
ENTRERRIOS-1	SANTA MARIA-1
ESTERO-1	SANTIAGO-2
FLORENA A-1	SANTIAGO-3
FLORENA-1	SIMON-1
GUARILAQUE-1	SM-4
LA CABANA-1	SURIMENA-1
LA GLORIA-1	TAME-2
LA HELIERA-1	UNETE-1
LA MARIA-1	VANGUARDIA-1
LA PUNTA-1	YALI-1
LETICIA-1	

LMV

ACHI-1
ALEJANDRIA-1
ALGARROBO-1
APURE-1
APURE-2
ARJONA-1
BETULIA-1
BOQUILLA-3
CICUCO-1
EL CASTILLO-1
GUEPAJE-1
LIGIA-1
MAGANGUE-1
MAGANGUE-2
MARSELLA-1
MONTELIBANO-1
PIJINO-1X
PINUELA-1
PIVIJAY-1
RIOMAR-1A
SAN BENITO-1
SAN JORGE-1
SUCRE-1
TIERRAFIRME-1
VIOLO-1A
YATI-1

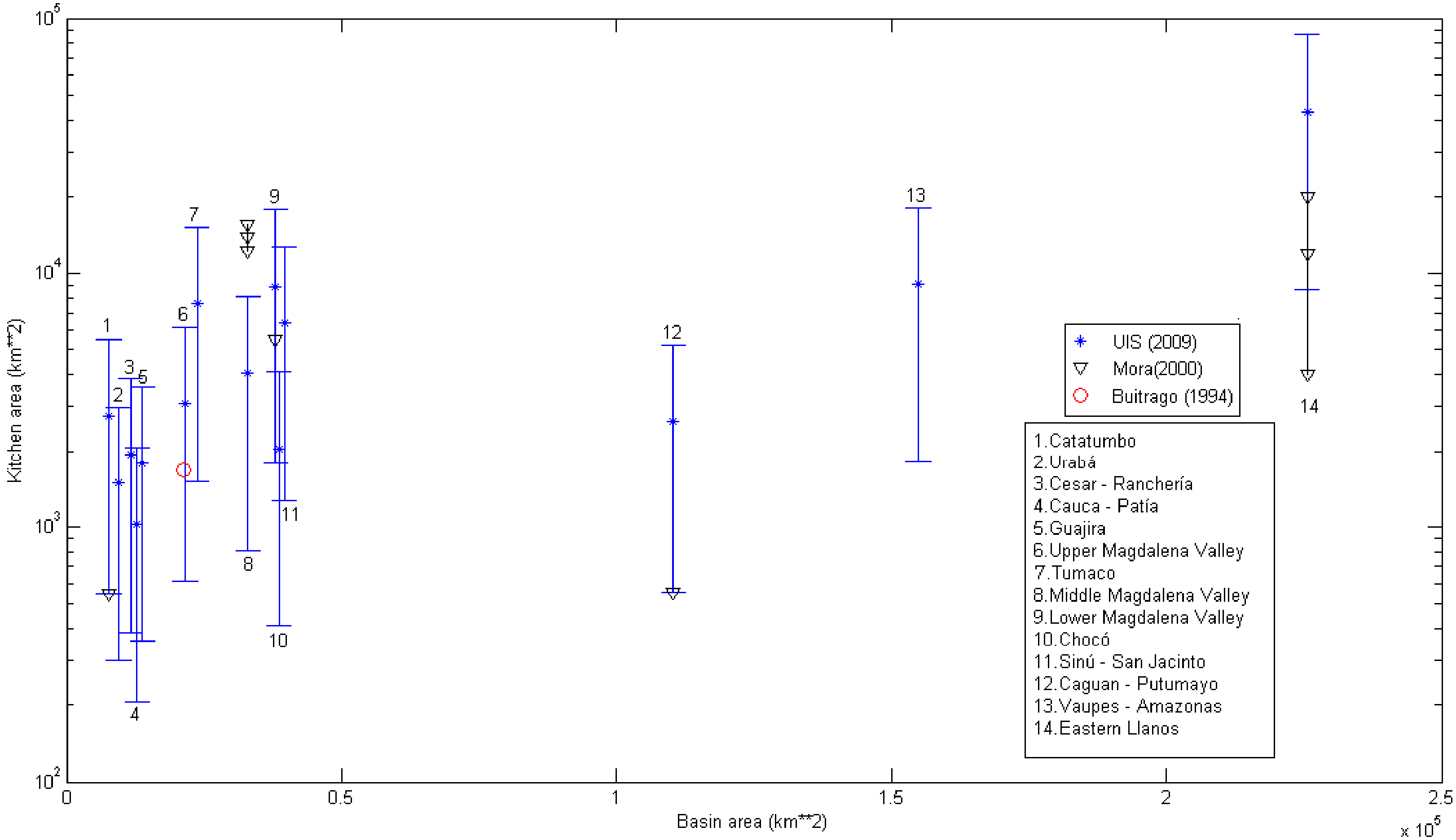
MMV

ARENOSA-1
BERLIN-2
CAPOTE-1
CASABE-199
ESCUELA-1
JERUSALEN-1
LLANITO-1
MONTERREY-1
MORALES-1
MUGROSA SUR-1
MUGROSA-5
NOREAN-1
PENA DE ORO-1
PICO-1
PIEDRAS-1
PPI-3
SAN FERNANDO X-1
TENERIFE-3

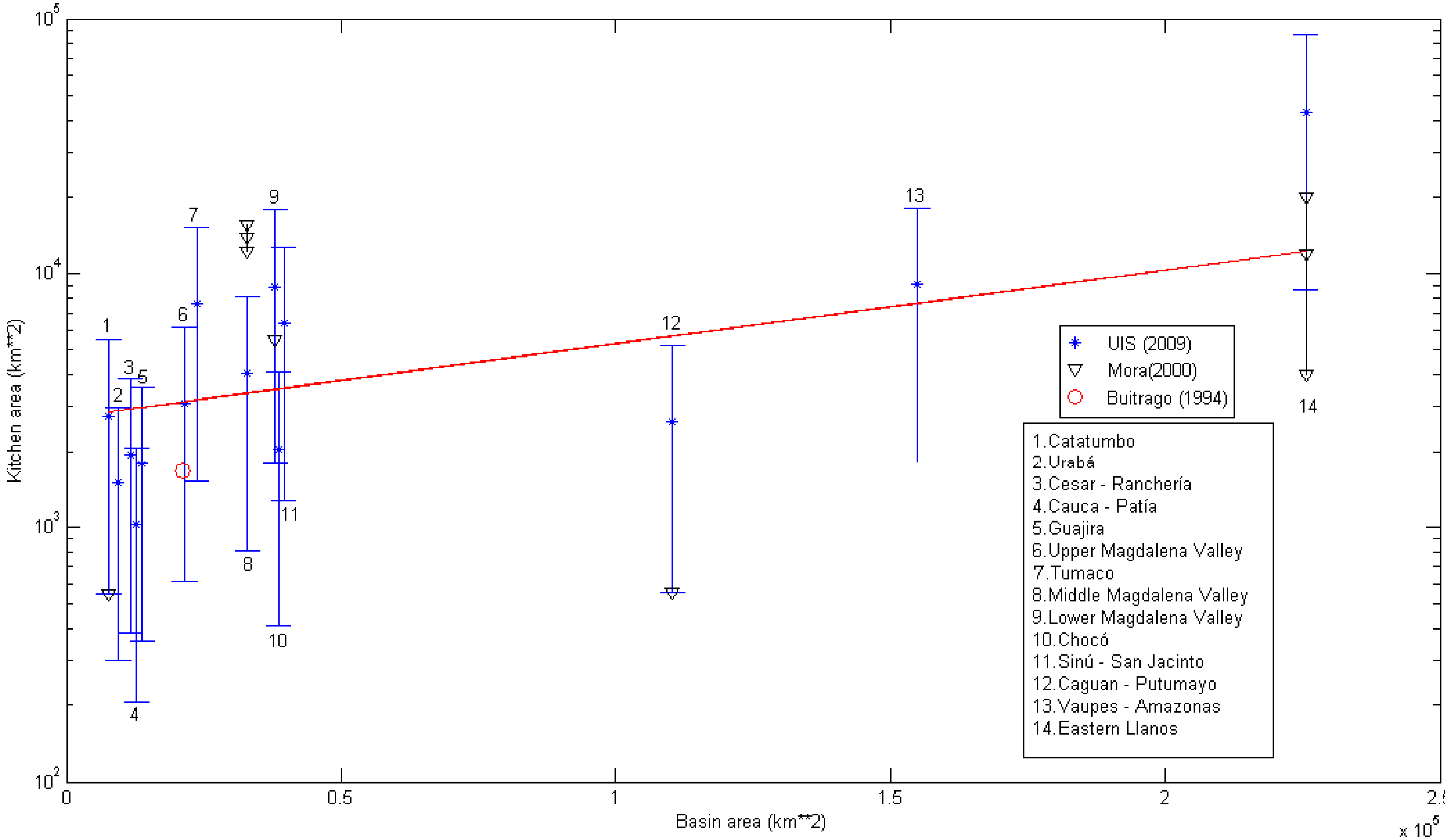
UMV

AMOYA-1	PALERMO-2
BALCON-6	PAUTA-1
BOGA-1	PEDERNALES_1
BOREAL-1	PIGOANZA-1
CERRO BUENAVISTA-1	PILU-1
CHENCHE-1	QUIMBAYA-2
CHIPALO-1	RIO SALDANA-1
COELLO-1	ROSITA-1
COYAIMA-1	SAN FRANCISCO-50
EL OLIVO-1	SANTA CLARA SUR-1
FLORENTINA-1	SANTA CLARA-2
HATO NUEVO-1	STRATIGRAPHIC-1
LA CANADA-1	SUAREZ-1
LOS MANGOS-1	TESALIA-1
LOS MANGOS-31	TOCAIMA-1
LOS MANGOS-4	TOLDADO-1
MICHU-1	TOMOGO-1
NILO-1	TOY-1
OLINI-1	VENGANZA-1
ORTEGA-1	YAVI-1
ORTEGA-12	

1. Identifying the source rock area



There is a trend that may well support a hypothetical assumption: the kitchen area α to the basin area



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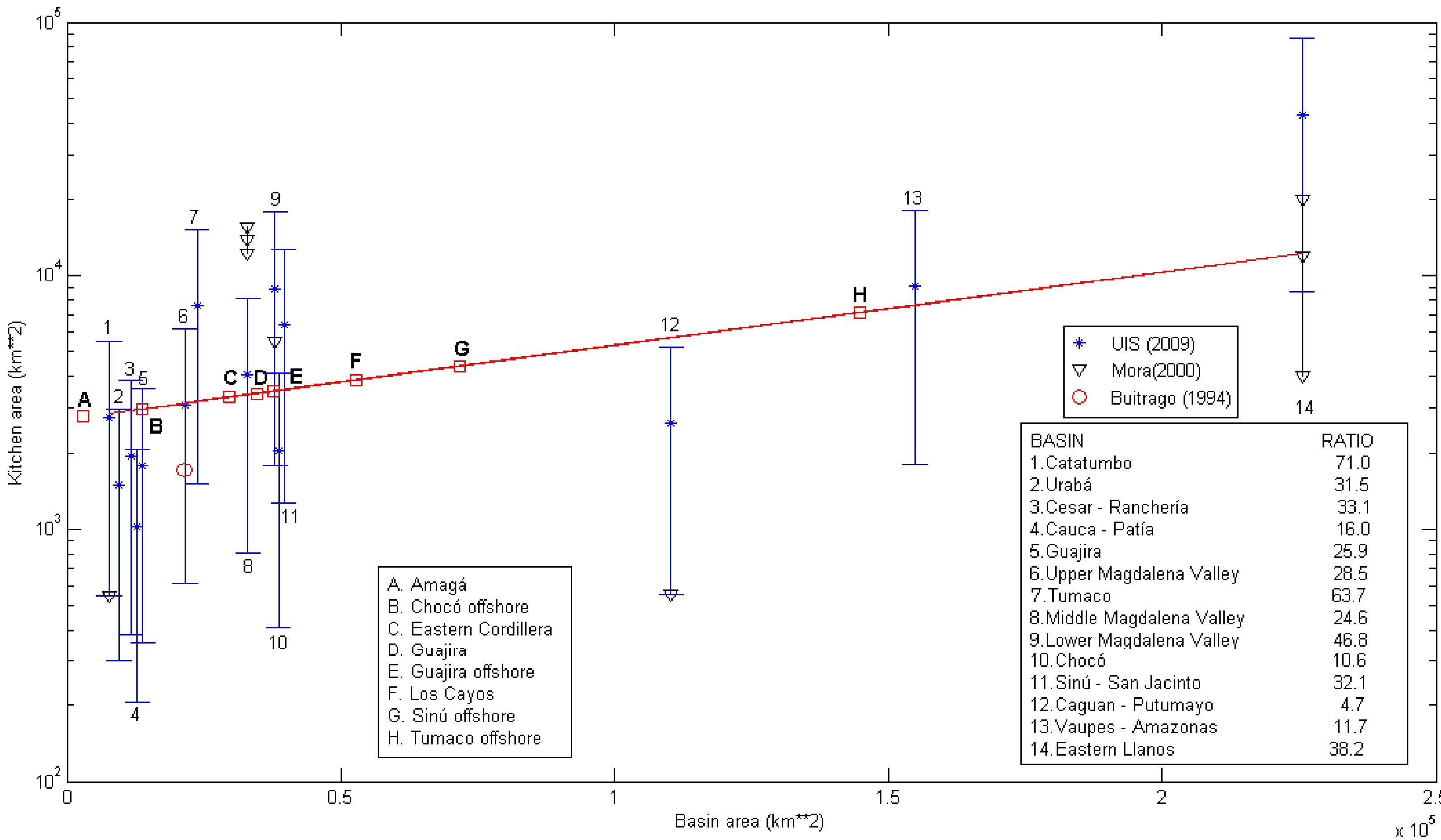
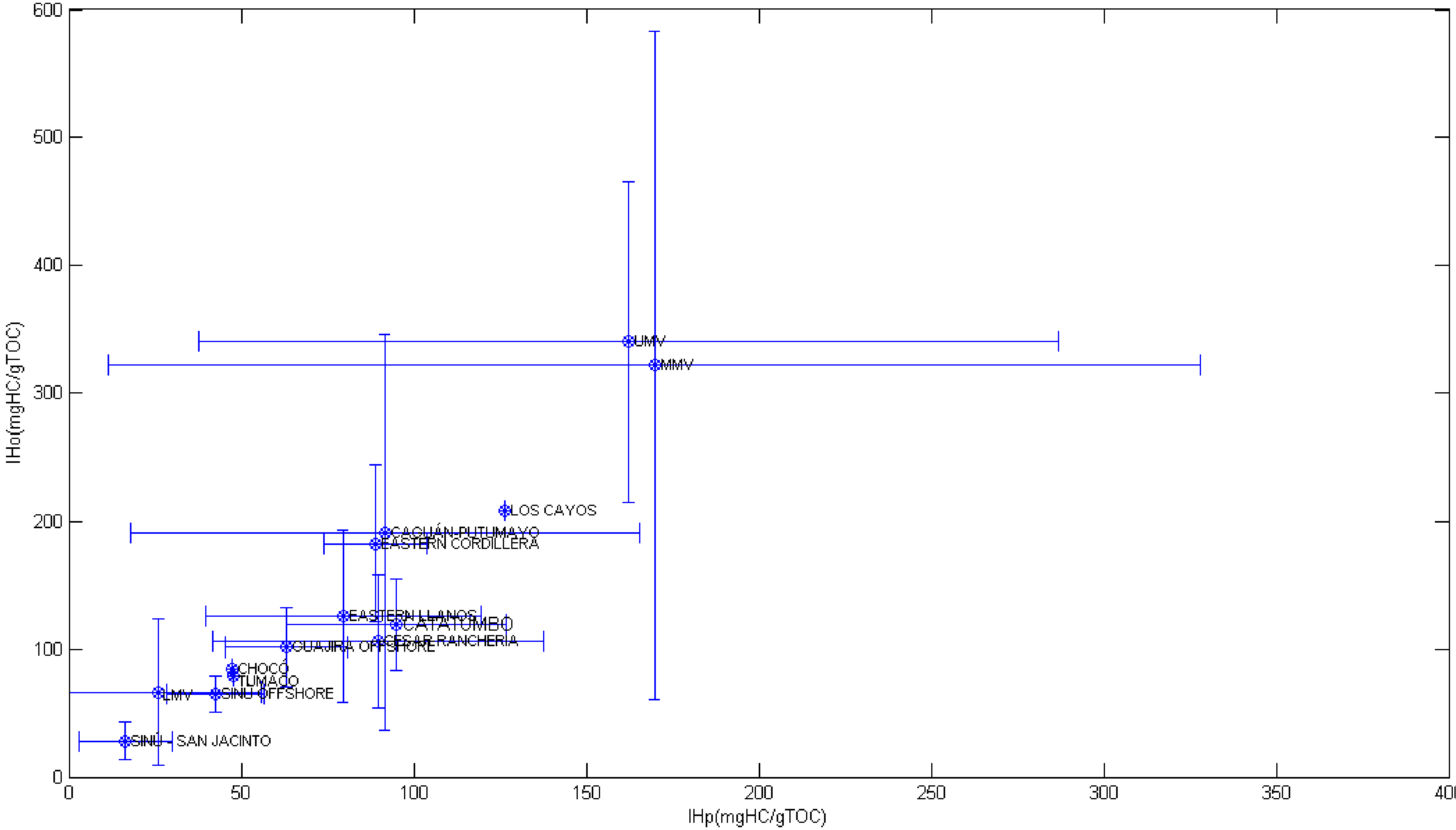
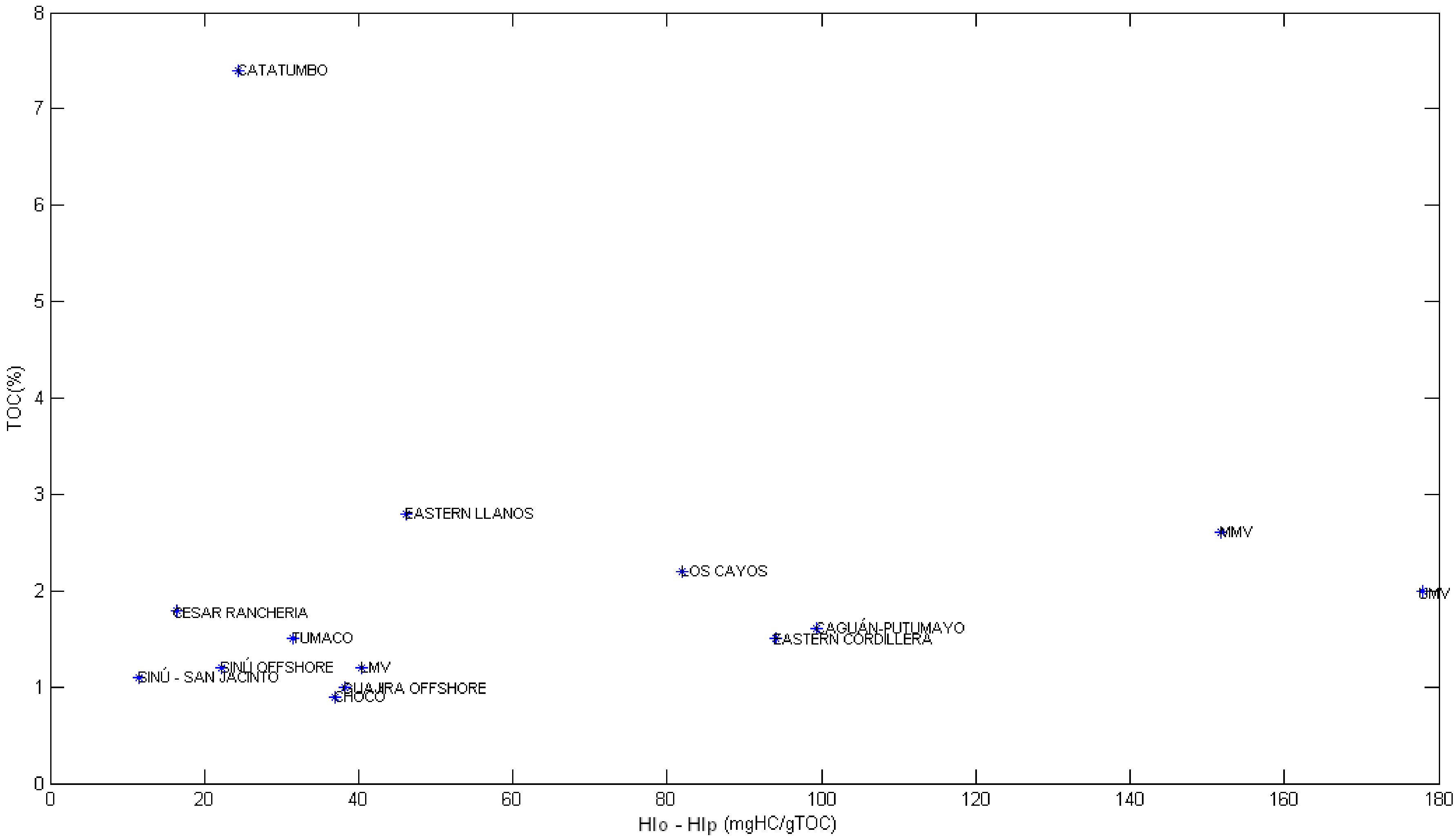
Now we are able to estimate the kitchen area in some frontier basins



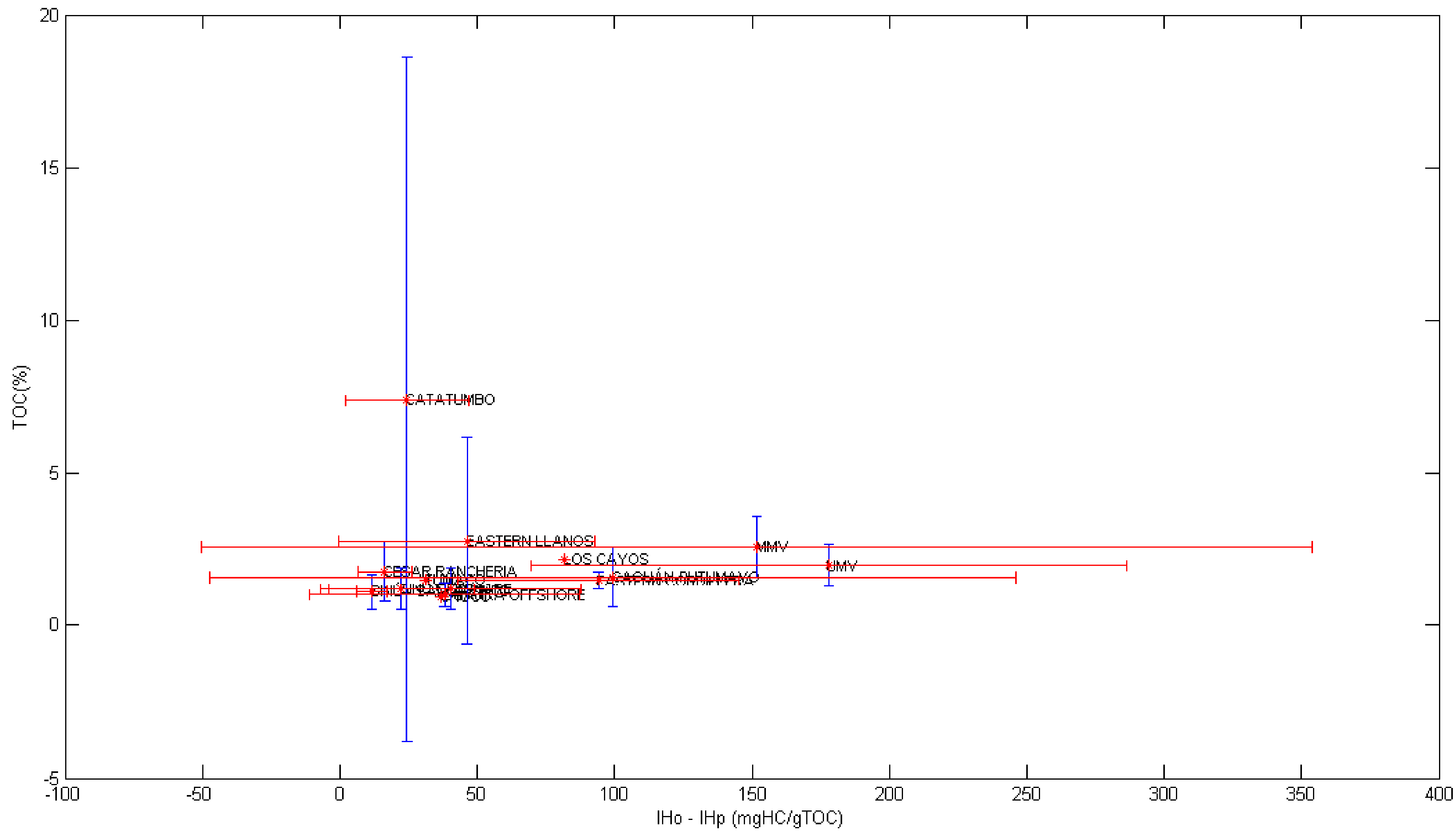
Other trends are confirming the mass of HC generated from the source rock



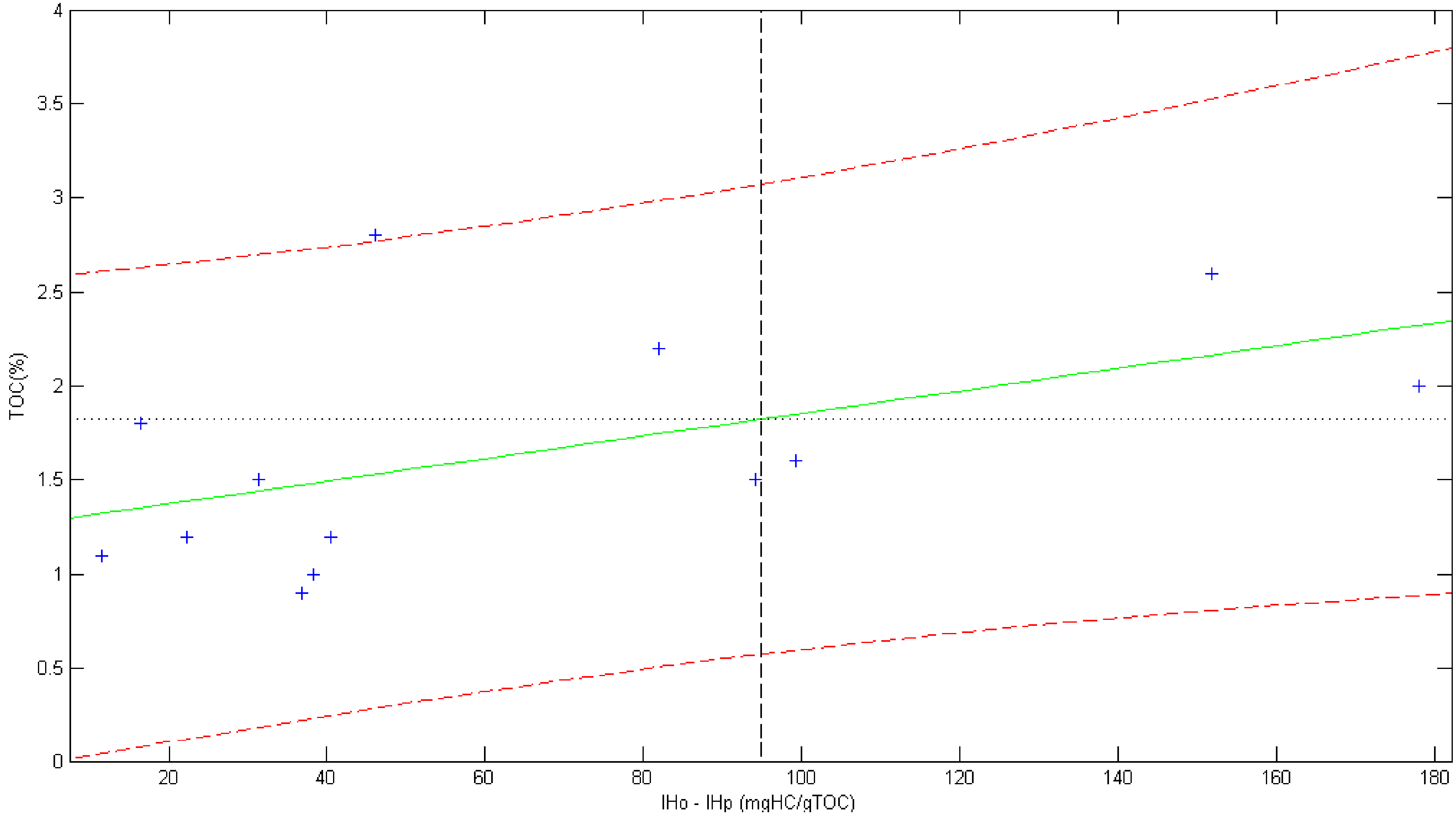
Steps 2 and 3: Is there any relation between TOC and the mass of HC generated in the Colombian basins?



There is a trend that may support a new hypothetical assumption: TOC(%) α to the mass of HC generated

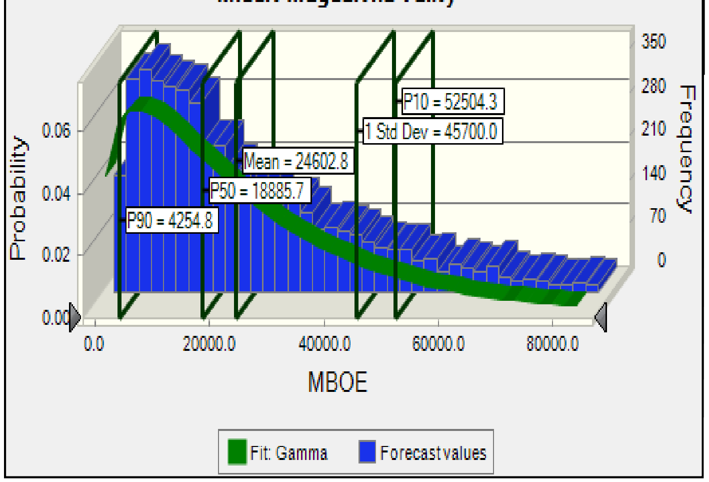


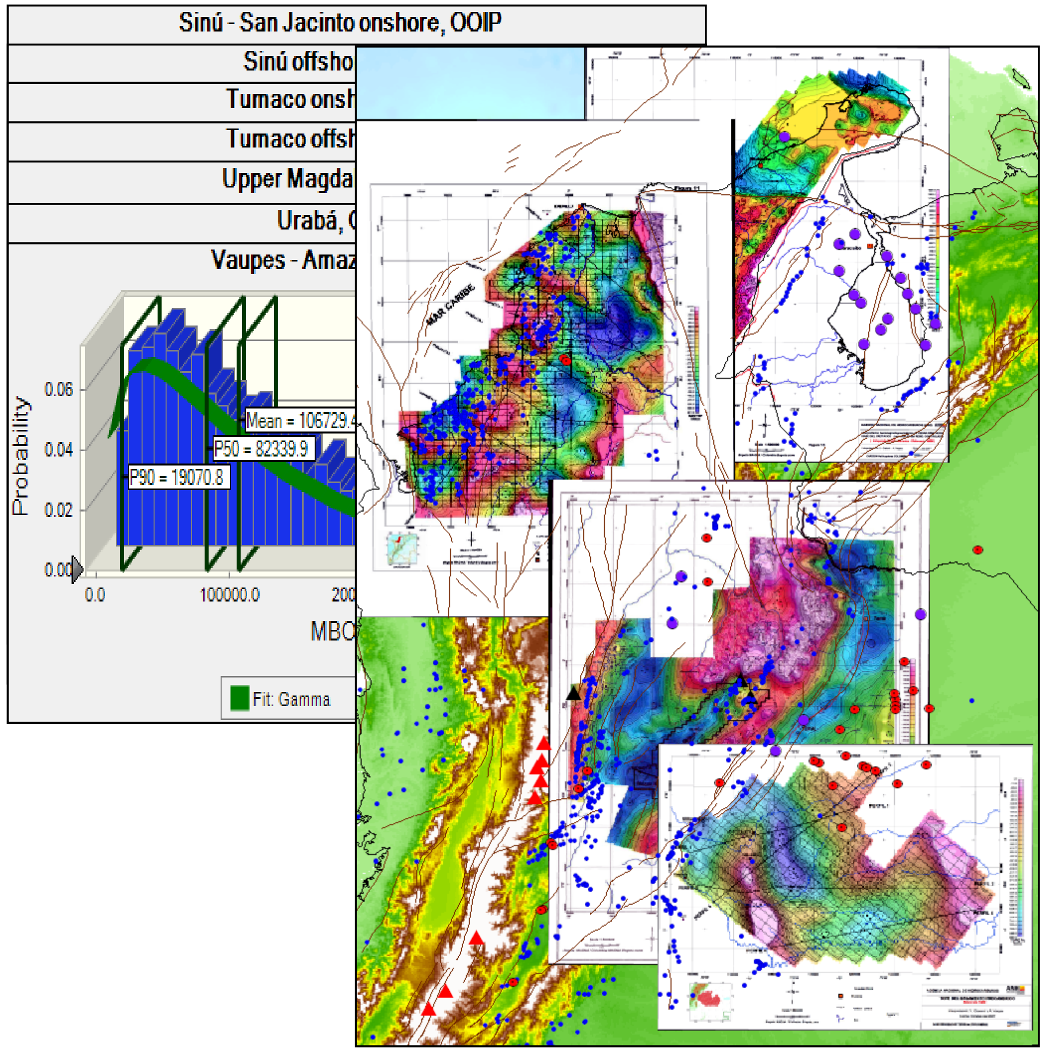
Now, knowing the TOC(%) of any basin, it is possible to calculate the mass of HC generated with degrees of confidence!



Estimations for every basin

Amagá, OOIP
Caguan - Putumayo, OOIP
Catatumbo, OOIP
Cauca - Patía, OOIP
Cesar - Ranchería, OOIP
Chocó offshore, OOIP
Chocó onshore, OOIP
Eastern Cordillera, OOIP
Eastern Llanos, OOIP
Guajira offshore, OOIP
Guajira onshore
Los Cayos, OOIP
Lower Magdalena Valley, OOIP
Middle Magdalena Valley





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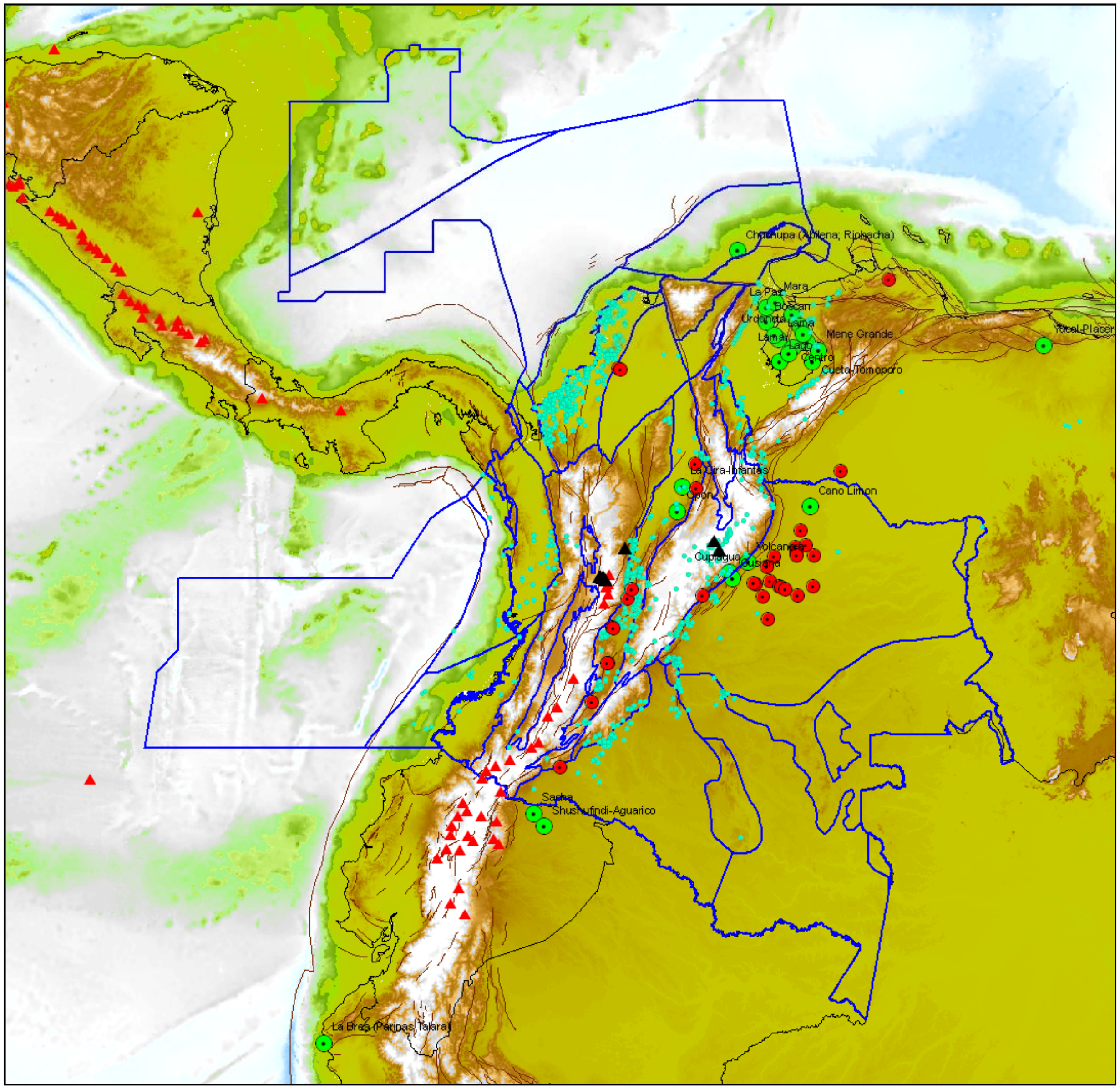
Agenda

- Introduction and geologic setting
- Methodology
- **Results**
- Conclusions

Potential resources in 21 basins



HC in place Colombian basins (BBOE)	
P90	P10
569,0	1.368,0

Undiscovered resources (BBOE)	
P90	P10
34,2	82,1

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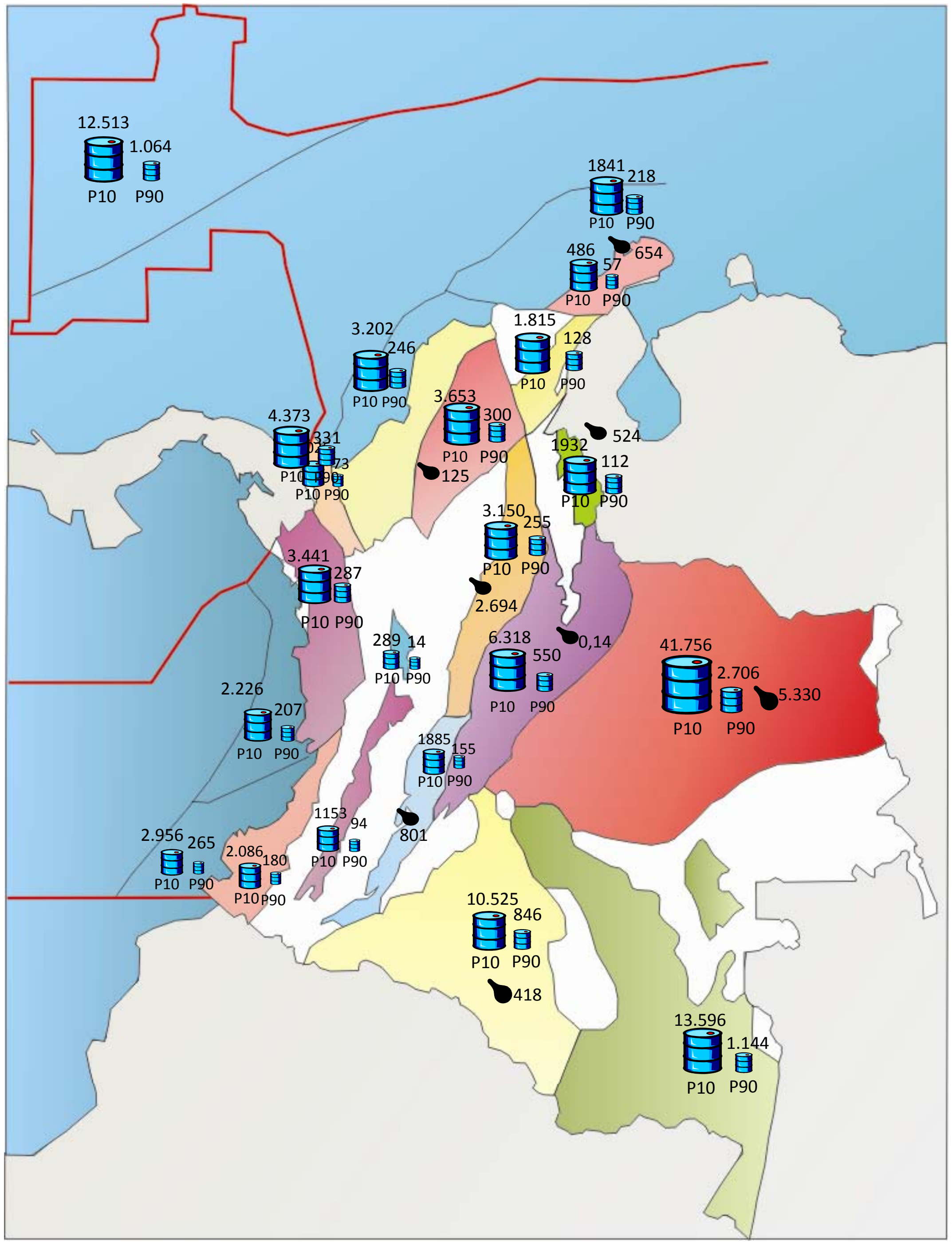

12.513
1.064
P10 P90
1841
218
P10 P90
654
486
57
P10 P90
1.815
128
P10 P90
3.202
246
P10 P90
3.653
300
P10 P90
125
524
4.373
331
P10 P90
73
P10 P90
1932
112
P10 P90
3.150
255
P10 P90
3.441
287
P10 P90
2.694
0,14
289
14
P10 P90
6.318
550
P10 P90
41.756
2.706
5.330
P10 P90
2.226
207
P10 P90
1885
155
P10 P90
801
1153
94
P10 P90
2.956
265
P10 P90
2.086
180
P10 P90
10.525
846
P10 P90
418
13.596
1.144
P10 P90

Agenda

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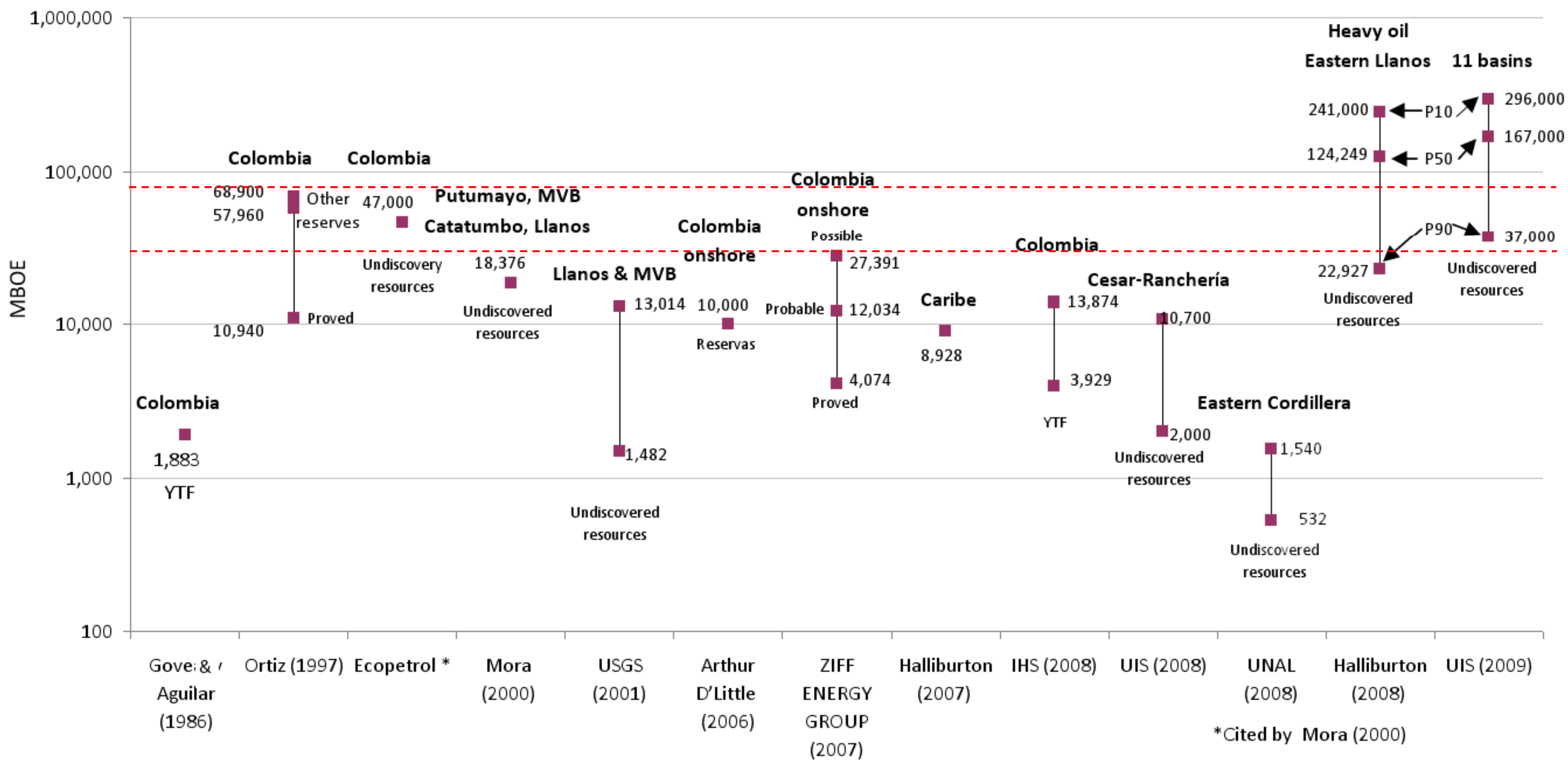
Assuming conservative scenarios (GR ~ 30% and RF ~ 20%), the undiscovered resources could range between 34,141.5 and 82,117.3 MBOE.



Recommendations and precautions

Given the regional nature of this study, it is suggested that a more representative data analysis of each basin be considered in order to refine the above undiscovered resource values.

Even accepting the numbers presented in this work, it would be necessary to systematically assess the geologic risk and the recovery factor.