Paleo-area Method

Silicate Weathering

Length	600	km	
Width	67	km	
Area	40200	km^2	
Yield	6.41	10^6 mol/km2/yr	Java (Dessert et al., 2003)
Yield/2	3.21	10^6 mol/km2/yr	one bicarbonate returned to atmosphere per divalent cation
Carbon uptake	128841	10^6 mol/yr	
Carbon uptake	1.3E+11	mol/yr	
Carbon uptake	**0.13**	Emol/m.y.	

Organic Carbon Burial

Area	40200	km^2	
POC yield	100	tons/km2/yr	New Zealand (Lyons et al., 2002)
	100000000	g/km2/yr	
	12	g/mol C	
	8333333	mol/km2/yr	
OC burial flux	3.4E+11	mol/yr	
	0.34	Emol/m.y.	
less 20% oxidized	**0.27**	Emol/m.y.	(Berner, 1982)

Paleo-erosion Rate Method

Mass flux	**346**	**10^15 kg/m.y. (Eg/m.y.)**	**copied from cell B36 below (Rowley, 1995)**
Silicate Weathering			
	0.2	mol/kg	(France-Lanord and Derry, 1997)
	3	dimensionless	(Meybeck, 1987)
CO2 uptake	**0.21**	**Emol/m.y.**	
OC gain	0.01	g/g	sediment OC - parent OC (France-Lanord and Derry, 1997; Bengal Fan sediments average 1% OC)
	12	mol/g	
Organic Carbon Burial	**0.29**	**Emol/m.y.**	

NEW CALEDONIA EROSION RATE

density	3000	kg/m3	**ROWLEY (1995) METHOD OF CALCULATING EROSION**
gravity	9.8	m/s2	
thickness	9000	m	Based on 7 km of oceanic crust and 2 km of upper mantle
pressure differential	**265**	**Mpa**	
P	264600000	Pa	
Dip of thrust	**5.5**	**degrees**	Mean of dips used by Rowley (1995)
theta	0.096	radians	
gamma	0.25		Topography proportionality constant (0.25 = 5 km at 400 km from thrust front)
T	99327	m	T = 1/(4*tan(theta)^2)*(gamma - ((density*9.8*gamma^2 + 4*tan(theta)*P)^0.5)/(2800^0.5*9.8^0.5))^2
T_km	99	km	Horizontal distance, thrust front to hinge of ramp syncline
St	99786	m	St = T/cos(theta) Length of ramp
eT	79	m	Elevation at T
D_T	9564	m	Depth at T
ACT	9654	m	ACT = (eT+D_T)/cos(theta/2) Length of trace of the ramp syncline axial plane
phi	1.52	radians	phi = (3.14-theta)/2 ramp syncline interlimb angle/2
phi	87.25	degrees	
area	962224719	m^2	Area eroded = St*ACT*sin(phi)
length	600	km	
volume	5.8E+14	m^3	
volume	**5.8E+05**	km^3	
duration	5	m.y.	38-33 Ma
volume flux	1.2E+05	km^3/m.y.	
mass flux	3.5E+17	kg/m.y.	
mass flux	**346**	**10^15 kg/m.y. (Eg/m.y.)**	

IF HALF VOLUME WAS PERIDOTITE (Discussion, paragraph #2)

olivine density	3300	kg/m3	
(half) volume	2.9E+14	m^3	
mass	9.5E+17	kg	
	0.32	per m.y.	(Kelemen and Matter, 2008)
	14.2	mol/kg	
CO2 uptake	**4.3**	**Emol/m.y.**	

CHECK ON ROWLEY CALCULATION, MAIN CENTRAL THRUST, HIMALAYAS

density	2800	kg/m3	**ROWLEY (1995) METHOD OF CALCULATING EROSION**
gravity	9.81	m/s2	
thickness		m	
pressure differential	560	Mpa	
P	560000000	Pa	
Dip of thrust	**5**	**degrees**	
theta	0.087	radians	
gamma	0.25		Topography proportionality constant (0.25 = 5 km at 400 km from thrust front)
T	231653	m	T = 1/(4*tan(theta)^2)*(gamma - ((density*9.8*gamma^2 + 4*tan(theta)*P)^0.5)/(2800^0.5*9.8^0.5))^2
T_km	232	km	Horizontal distance, thrust front to hinge of ramp syncline
St	232538	m	St = T/cos(theta) Length of ramp
eT	120	m	Elevation at T
D_T	20267	m	Depth at T
ACT	20407	m	ACT = (eT+D_T)/cos(theta/2) Length of trace of the ramp syncline axial plane
phi	1.53	radians	phi = (3.14-theta)/2 Ramp syncline interlimb angle/2
phi	87.50	degrees	
area	4740838643	m^2	Area eroded = St*ACT*sin(phi)
length	2500	km	
volume	1.2E+16	m^3	
volume	**1.2E+07**	km^3	**1.0 x 10^7 km^3 is the volume reported by Rowley (1995) for delP 560 MPa and 5 degree dip**
duration	5	m.y.	20-15 Ma
volume flux	2.4E+06	km^3/m.y.	
mass flux	6.6E+18	kg/m.y.	
mass flux	6637	10^15 kg/m.y.	(or Eg/m.y.)

COMPARISON WITH OTHER APPROACHES TO ESTIMATING VOLUME ERODED

Length	600	km	
Width	67	km	
Thickness	10	km	
Volume	**402000**	km^3	New Caledonia map and cross section ("ballpark inspection")
Volume	**577335**	km^3	Method of Rowley (1995)
Volume	**2844503**	km^3	Proportioning to Himalayas (*600 km/2500 km)

Paleo-sedimentation Rate Method

(Cluzel et al., 2001)

Age (Ma)	Depth (m)	Thickness (m)	Duration (m.y.)	Sed. rate (m/m.y.)	Tectonic stage
33.9	0				
37.2	2250	2250	3.3	**682**	flysch
65	2400	150	27.8	5	pelagic phase
95	2900	500	30	17	rift phase

Length	800	km	Map (+100 km at ends)
NNCB	70	km	width of N. New Caledonia Basin (Collot et al., 2008)
NC	30	km	~shortening on NC (Cluzel et al., 2001)
LB	100	km	symmetry
Total width	200	km^2	
Area	160000	km^3	
Sed. Rate	0.682	km/m.y.	(see above, Cluzel et al., 2001)
Volume flux	109091	km^3/m.y.	
Density	2	10^15 g/km3	
Mass flux	2.18E+20	g/m.y.	
Mass flux	**218**	Eg/m.y.	
Silicate Weathering			
	0.2	mol/kg	(France-Lanord and Derry, 1997)
	3	dimensionless	(Meybeck, 1987)
CO2 uptake	**0.13**	**Emol/m.y.**	
OC gain	0.01	g/g	sediment OC - parent OC (France-Lanord and Derry, 1997; Bengal Fan sediments average 1% OC)
	12	mol/g	
Organic Carbon Burial	**0.18**	**Emol/m.y.**	

NOTE: Values in table are linked to calculations on previous 3 sheets

TABLE 1. ESTIMATED CARBON FLUXES

Method	Silicate weathering (Emol $m.y.^{-1}$)	Organic C burial (Emol $m.y.^{-1}$)	Volcanic CO2 (Emol $m.y.^{-1}$)	Totals (Emol $m.y.^{-1}$)
Paleo-area[a]	0.13	0.27	---	
Erosion Rate[b]	0.21	0.29	---	
Sedimentation Rate[c]	0.13	0.18	---	
	---	---	0.03	
minimum	0.13	0.18	0	0.3
maximum	0.21	0.29	0.032	0.5

a) based on modern yield measurements

b) sediment-parent difference; erosion rate by method of Rowley (1995)

c) same as b), but sedimentation rate data from Cluzel et al. (2001)

Relationship between total carbon and pCO2 (SEE GRAPH ON NEXT SHEET)

Spreadsheet from Albarede for his Figure 9.3 (Geochemistry, Albarede, 2009)

Ks/[Ca]	K1	K2	alpha		
4.70E-05	1.00E-06	7.70E-10	2.84E-02		
	H	SCO2	PCO2	Tot C	PCO2
		mol/kg	atm	(Emol)	ppmv
7	1.00E-07	0.0068	0.021	9.47	21493
7.1	7.94E-08	0.0053	0.014	7.39	13561
7.2	6.31E-08	0.0041	0.009	5.80	8556
7.3	5.01E-08	0.0033	0.005	4.56	5399
7.4	3.98E-08	0.0026	0.003	3.60	3406
7.5	3.16E-08	0.0020	0.002	2.85	2149
7.6	2.51E-08	0.0016	0.001	2.27	1356
7.7	2.00E-08	0.0013	0.001	1.80	856
7.8	1.58E-08	0.0010	0.001	1.44	540
7.9	1.26E-08	0.0008	0.000	1.16	341
8	1.00E-08	0.0007	0.000	0.93	215
8.1	7.94E-09	0.0005	0.000	0.75	136
8.2	6.31E-09	0.0004	0.000	0.61	86
8.3	5.01E-09	0.0004	0.000	0.50	54
8.4	3.98E-09	0.0003	0.000	0.41	34
8.5	3.16E-09	0.0002	0.000	0.34	21

Volume of seawater (liters)
1.4E+21

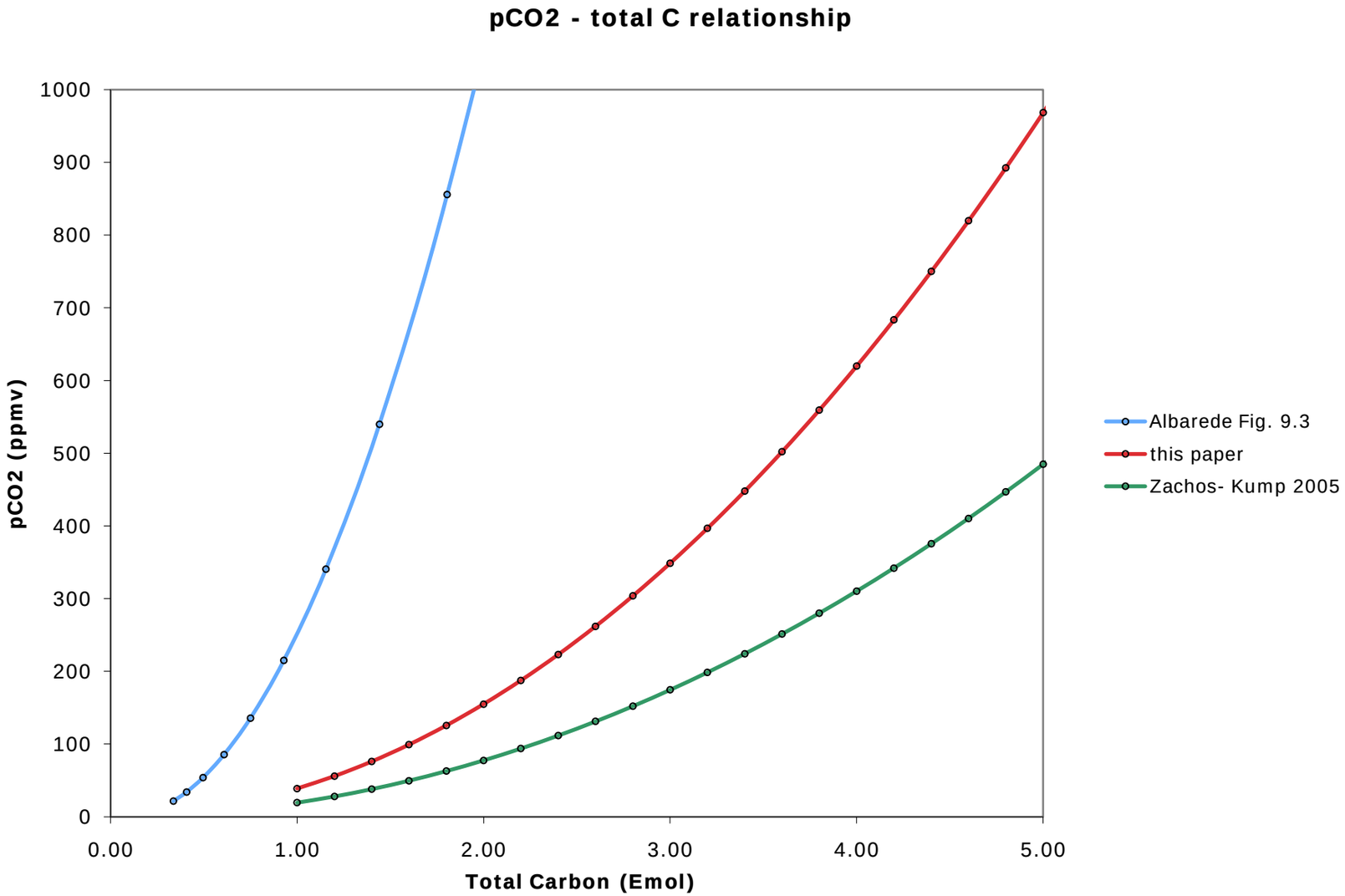
Zachos and Kump (2005)

Ctot	PCO2
Emol	ppmv
1	19
1.2	28
1.4	38
1.6	50
1.8	63
2	78

THIS PAPER

Ctot	PCO2
Emol	ppmv
1	39
1.2	56
1.4	76
1.6	99
1.8	126
2	155

2.2	94	2.2	188
2.4	112	2.4	223
2.6	131	2.6	262
2.8	152	2.8	304
3	175	3	349
3.2	199	3.2	397
3.4	224	3.4	448
3.6	251	3.6	502
3.8	280	3.8	559
4	310	4	620
4.2	342	4.2	683
4.4	375	4.4	750
4.6	410	4.6	820
4.8	447	4.8	893
5	485	5	968
5.2	524	5.2	1048

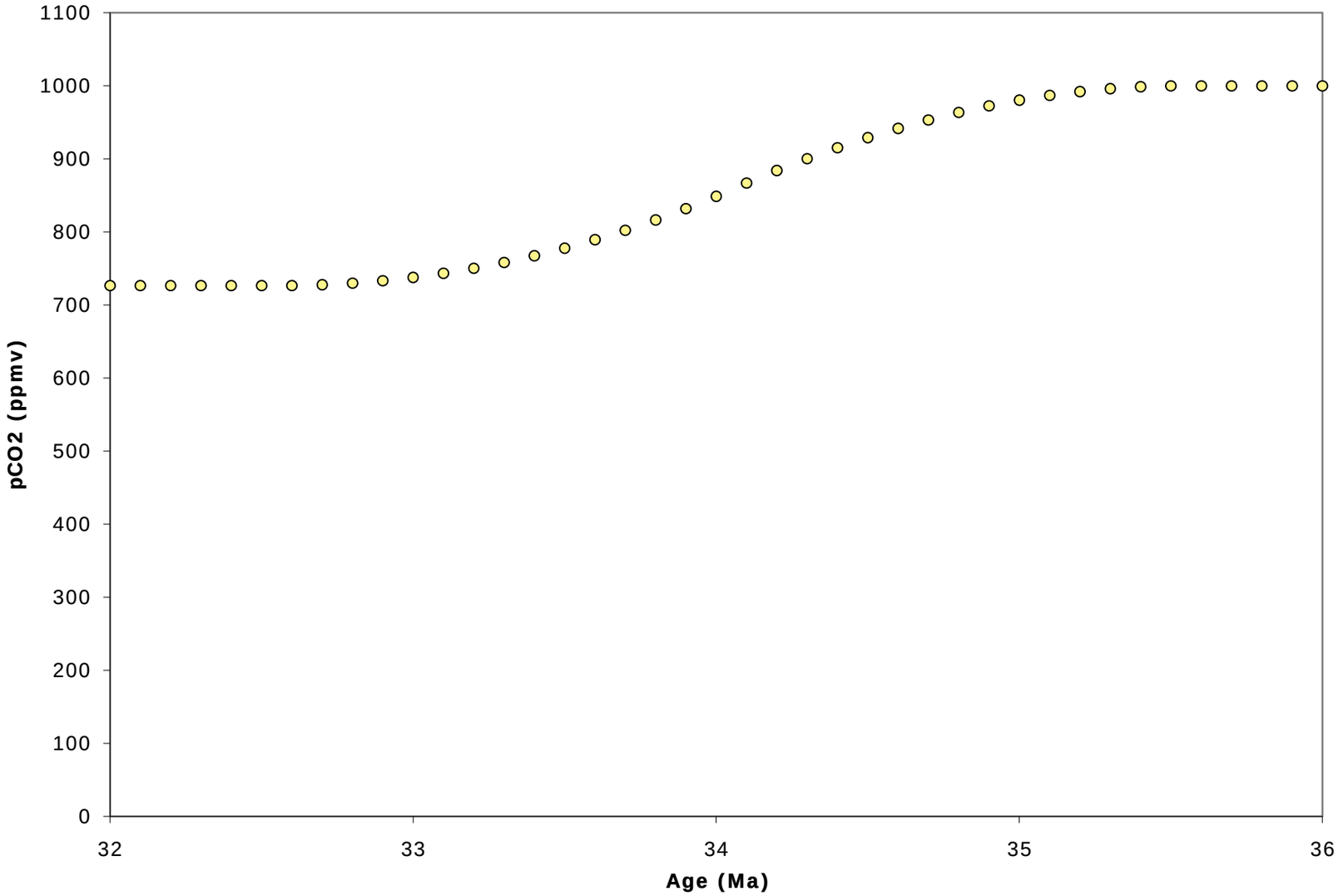

pCO2 - total C relationship
pCO2 (ppmv)
1000
900
800
700
600
500
400
300
200
100
0
0.00
1.00
2.00
3.00
4.00
5.00
Total Carbon (Emol)
Albarede Fig. 9.3
this paper
Zachos- Kump 2005

Sample integration to solve for pCO2 (Fig. 2 model results obtained using Berkeley Madonna…
…with time step of 0.1 m.y. and Runge-Kutta 4)

Age (Ma)	Time (m.y.)	- d TOC/dt (Emol/m.y.)	TOC (Emol)	pCO2 (ppmv)
36	0	0	5.08	1000
35.9	0.1	0	5.08	1000
35.8	0.2	0	5.08	1000
35.7	0.3	0	5.08	1000
35.6	0.4	0	5.08	1000
35.5	0.5	0	5.08	1000
35.4	0.6	0.033	5.08	998
35.3	0.7	0.067	5.07	996
35.2	0.8	0.100	5.06	992
35.1	0.9	0.133	5.05	987
35	1	0.167	5.03	980
34.9	1.1	0.200	5.01	972
34.8	1.2	0.233	4.99	963
34.7	1.3	0.267	4.96	953
34.6	1.4	0.300	4.93	942
34.5	1.5	0.333	4.90	929
34.4	1.6	0.367	4.86	915
34.3	1.7	0.400	4.82	900
34.2	1.8	0.433	4.78	884
34.1	1.9	0.467	4.73	867
34	2	0.5	4.68	848
33.9	2.1	0.467	4.63	832
33.8	2.2	0.433	4.59	816
33.7	2.3	0.400	4.55	802
33.6	2.4	0.367	4.51	789
33.5	2.5	0.333	4.48	778
33.4	2.6	0.300	4.45	767
33.3	2.7	0.267	4.42	758
33.2	2.8	0.233	4.40	750
33.1	2.9	0.200	4.38	743

33	3	0.167	4.36	738
32.9	3.1	0.133	4.35	733
32.8	3.2	0.100	4.34	730
32.7	3.3	0.067	4.33	727
32.6	3.4	0.033	4.33	726
32.5	3.5	0	4.33	726
32.4	3.6	0	4.33	726
32.3	3.7	0	4.33	726
32.2	3.8	0	4.33	726
32.1	3.9	0	4.33	726
32	4	0	4.33	726

NOTE: $pCO_2 = 38.74*(TOC)^2$


1100
1000
900
800
700
600
500
400
300
200
100
0
pCO2 (ppmv)
32
33
34
35
36
Age (Ma)

Miscellaneous Calculations

kg Mg_2SiO_4 => mol C

1	kg olivine	
1000	g olivine	
140.7	g/mol	
7.1	mol olivine	
14.2	**mol Mg**	

Figure 1D calculation (400 km^3 Mg_2SiO_4 = 100 ppmv CO2)

Volume	400	km^3	
Volume	4E+11	m^3	
Density	3300	kg/m3	
Mass	1.32E+15	kg olivine	
Number	*1.88E+16*	*mol Mg=C*	
Mass atm	5.00E+21	g	Kump
Mean mol wt	29	g/mol	Kump
Number	1.72E+20	mol	
100 ppmv	0.0001		
Number	*1.72E+16*	*mol C*	

Laboratory and Oman olivine carbonation kinetic data

olivine carb.	1E-14	/s	(O'Connor et al., 2004; Kelemen & Matter, 2008)
	31536000		
olivine carb.	3.1536E-07	/yr	
olivine carb.	**0.32**	**/m.y.**	

POSSIBLE REDUCTION IN VOLCANIC DEGASSING WHEN SUBDUCTION ZONE WAS JAMMED, AND WATER DELIVERY HALTED

1000	km	Length jammed	
1.6	Emol/m.y.	Global arc volcanism	(Hayes and Waldbauer, 2006)
50000	km	Length of subduction zones	(Bird, 2003)
2	per cent	of above	
0.03	Emol/m.y.	New Caledonian perturbation	