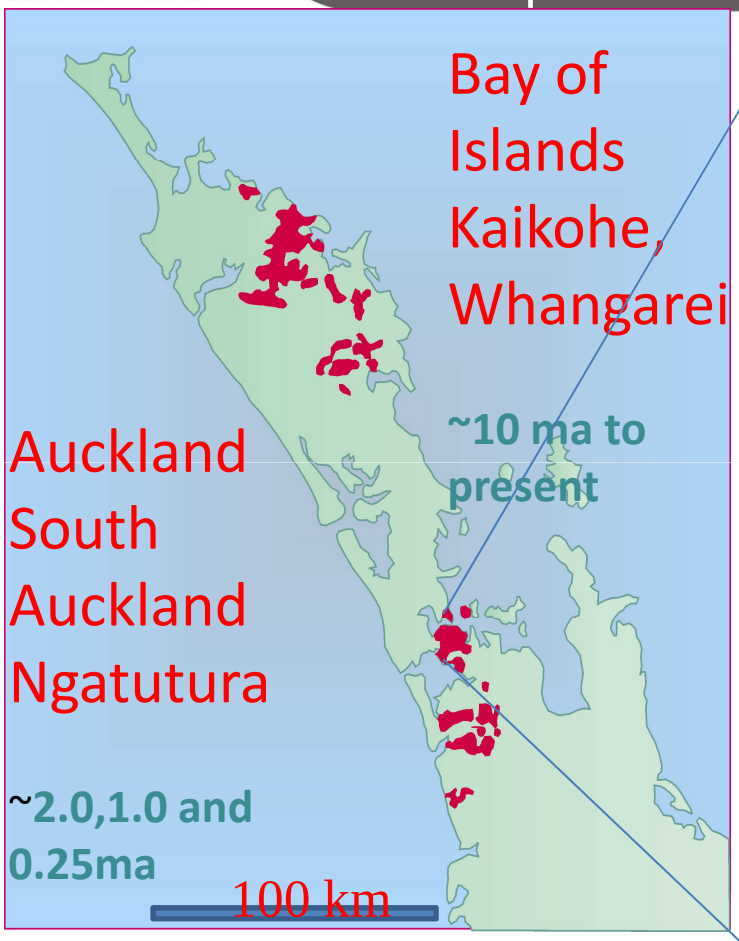
Multiple Dating Methods in the Auckland Volcanic Field: Including the Kitchen Sink

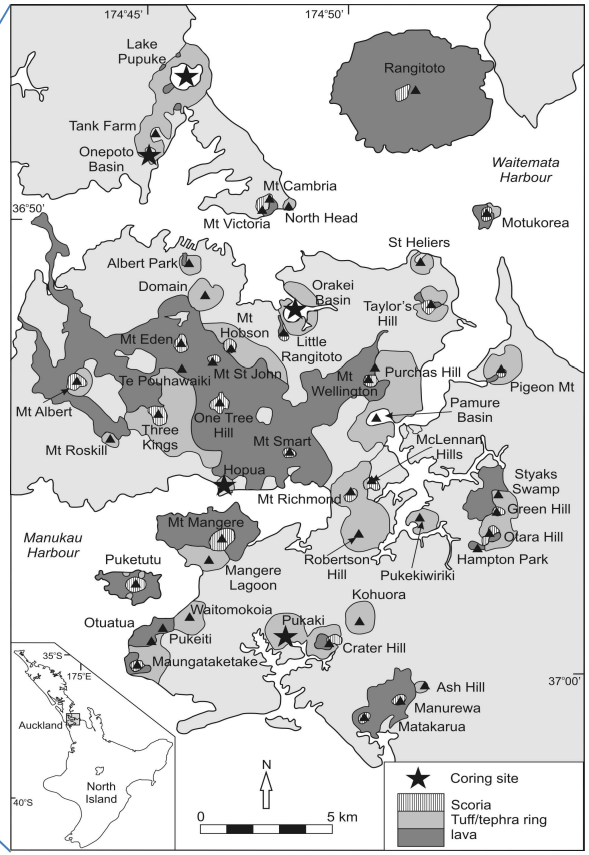
Mark Bebbington and Shane J. Cronin

[1]*Volcanic Risk Solutions, Massey University, Palmerston North, New Zealand*

Intraplate field volcanism in northern New Zealand



Auckland Volcanic Field



50(?) small basaltic volcanoes

young (~250,000 years)

Most recent eruption ~600 years ago

Restricted area (30x15 km)

Volumes typically 10^5 -10^7 m^3

Constructing an Age-model for the AVF

Decreasing reliability

Data:

- Stratigraphy, ~33 vents constrained in at least one direction
- Age determinations
  - C14, ~13 vents
  - Tephrostratigraphy (Molloy et al 2009), 24+ tephra in 5 cores
  - Ar-Ar, ~4 vents
  - **Magnetic (Cassidy and others), 5 "coeval" vents**
  - Thermoluminesence, 2 vents
  - K-Ar, unreliable due to excess Ar
- Relative geomorphology or weathering

Also: known vent locations, reasonable volume data

But: evidence of multiple phases at single vents

Core Data

24+ tephras within cores (Molloy et al. 2009). Thicknesses known, ages inferred from direct dating, tephrochronology or accumulation rates

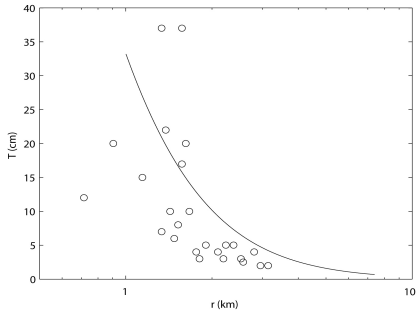
ID	Thickness (mm)					Age (ka)				
	Pupuke	Hopua	Orakei	Onetopo	Pukaki	Pupuke	Hopua	Orakei	Onetopo	Pukaki
AVF24	22					0.8±0.1				
AVF23		3					10.0±0.7			
AVF22					1					15.1±0.7
AVF21		290			3		20.0±0.7			19.7±0.7
AVF20		235			3		20.5±0.7			19.7±0.7
AVF19					1					24.4±0.8
AVF18		40	8		0.5		26.6±0.8	24.5±0.8		24.7±0.8
AVF17			5					24.7±0.8		
AVF16					50					25.5±0.8
AVF15			12					26.7±0.9		

etc.

Can invert the simple ashfall-attenuation function of Rhoades et al., 2002:

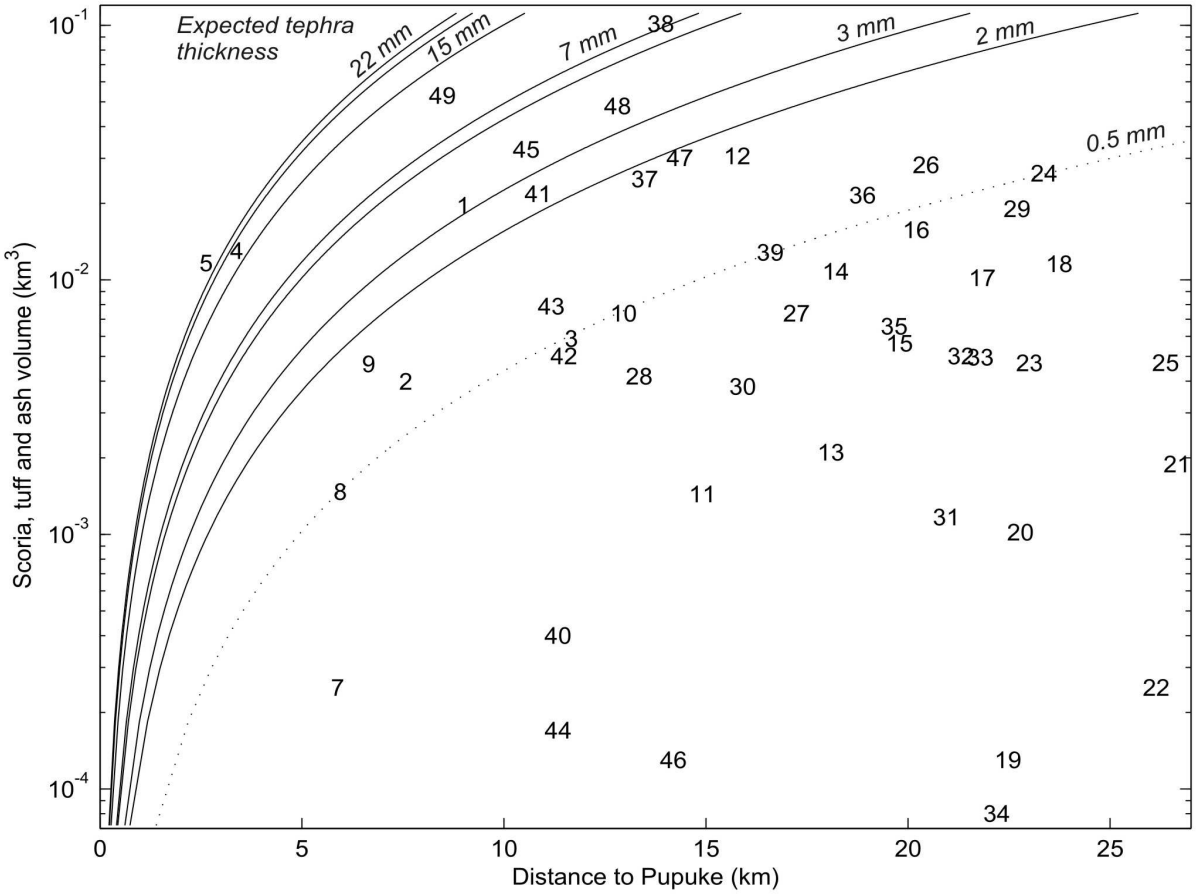
$$r = -1.85V^{1/3} + \exp\left[(8.67 + 1.13\log V - \log T)/2.38\right]$$

V = volume (km^3); T = thickness (cm); r = distance (km).



Validated against 1977 Ukinrek Maars eruption:

Tephra Attenuation (Pupuke)



- Wind-direction (low level) assumed random throughout record
- Stratigraphy must be maintained
- Assigned tephras must be consistent with reliable dates
- Tephras must not “skip-over” sites to be only at distal areas
- All tephras must be assigned

Age/Ordering Results

Resulting ordering/age model via Monte Carlo simulation

Name	Mean Age (ka)	Age Error (ka)	Min Order	Max Order
.....	...	...	...	...
Maungataketake	41.4	0.4	11	15
One Tree Hill	37.4	0.7	12	17
Motukorea	36.1	0.9	13	20
Mt Albert	35.2	0.9	14	21
Kohuora	35.1	1.0	13	21
Crater Hill	34.1	0.3	15	22
Hopua Basin	33.6	0.4	18	23
Puketutu	3.0	0.5	19	25
North Head	32.9	0.4	19	26
Hampton Park	32.4	4.8	12	41
Panmure Basin	32.3	0.3	21	27
Taylors Hill	32.0	1.9	13	39
Mt Roskill	32.0	1.9	16	34
Ash Hill	31.8	0.2	21	30
McLennan Hills	31.7	0.2	22	30
Mt Victoria	31.5	0.6	22	33
Mt Cambria	31.4	1.2	16	38
Wiri Mountain	30.9	0.4	24	32
Mt Richmond	29.9	0.6	25	35
Three Kings	28.8	0.3	29	35
Mt Eden	28.4	0.3	31	36
Waitomokia	28.1	0.8	27	39

etc.

"Coeval" events are 4ka apart, and interspersed with other events

Palaeomagnetic Excursions

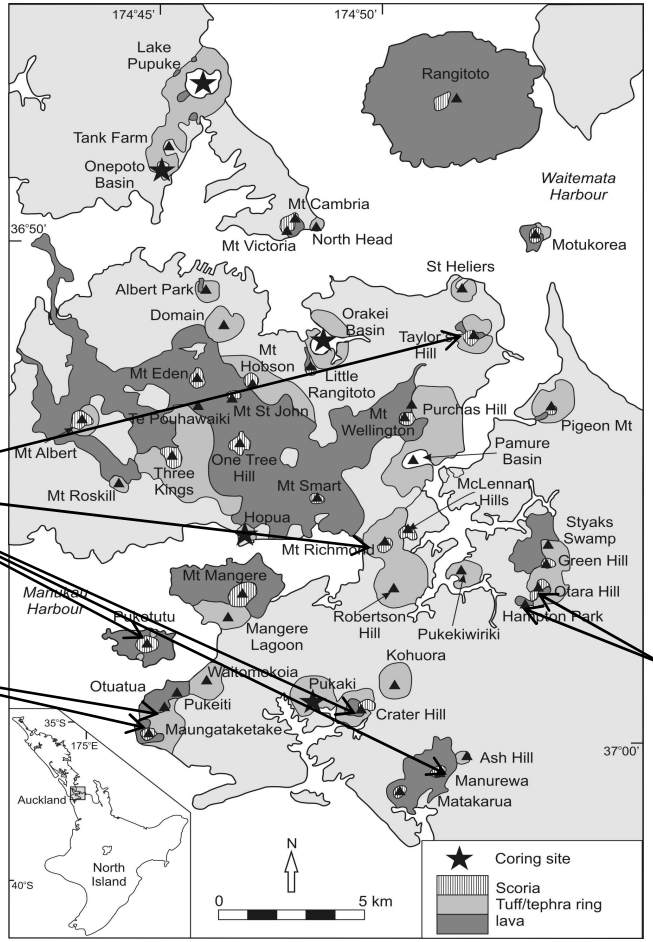
Laschamp at 40.4 ± 1.1 ka (Guillou et al, 2004)
Mono Lake at 32.4 ± 0.3 ka (Singer, 2007).
- Both are considered to last approximately 1 ka.

Cassidy and Locke (2009, 2010) suggest:

A) In ML [within 0.1ka?]
[TH at slightly different time?]

C) Identical magnetism
- within 0.1ka?

Stratigraphy:
(Waitomokoia > Pukeiti > Otuataua)
- Waitomokoia much older than estimated



D) Others have normal magnetism, cannot be in excursion, except possibly:
- Tank Farm
- Onepoto
- St Heliers
- Orakei Basin
- Hopua
- Pukaki
- Kohuora
- Little Rangitoto
- Pukeiti

(Cassidy, pers. comm.).

B) Contemporaneous
- within 0.1ka

Paleomagnetism: Conflict with C14 ages?

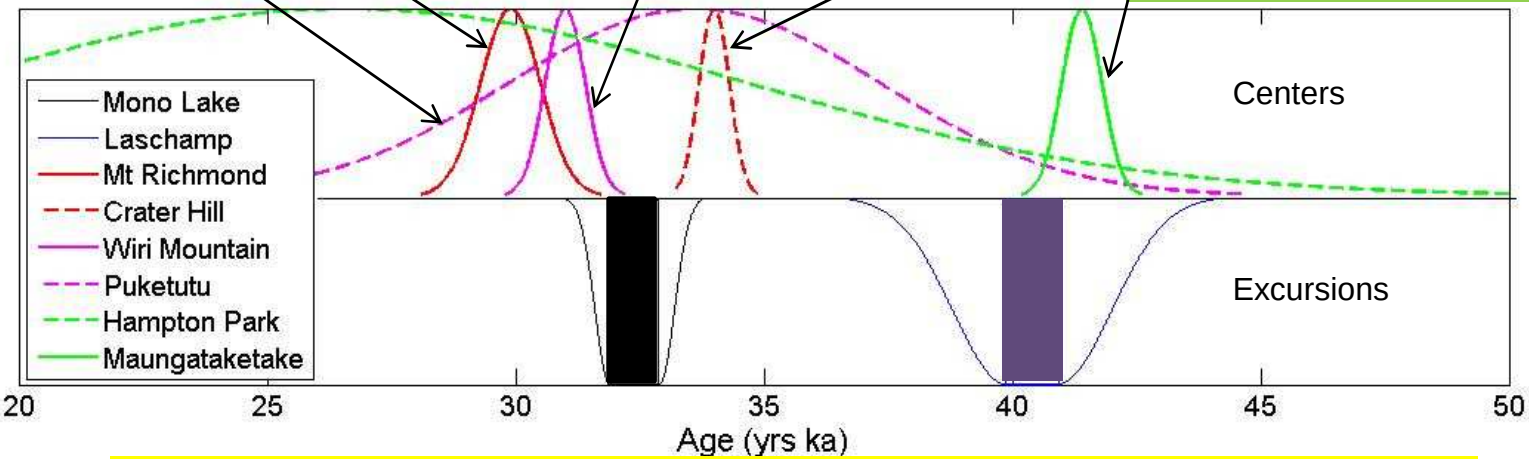
MR - **too young**. Lava from one of Robertson Hill, McLennan Hills, MR (Sandiford et al 2002).
MH ~ 31.7 ± 0.2 ka (C14),
so attribute 29.9 ± 0.6 ka to RH

WM – **young?** 2 C14 ages, both wood. 30.3 ka ± 0.5 ka from Mt Wiri Quarry, 32.9 ± 0.7 ka (within excursion limits) from beneath Wiri lava

CH - **too old**. 2 C14 ages. Younger wood in tuff, older wood overlain by tuff and underlain by grey-green tuff. Position and earlier C14 age consistent with Kohuora (32.0 ± 2.0 ka via sedimentation rate).

Puketutu – OK (tephrostratigraphy)

Maungataketake – Older than Laschamp?
- Older than Otuatua



Tephras AV6-AV8 match ML. No tephras match the Laschamp

Redo tephra matching

.....

Assign AV11 to ~~Wiri Mountain~~ *Robertson Hill.*

Assign AV9 to Panmure Basin

Assign AV6(Pukaki) to Crater Hill

Assign AV18,20,21 to Mangere Lagoon, Mt Mangere and Mt Smart, respectively

Assign AV8(Orakei,Pukaki) to Puketutu

Assign AV16 to ~~Waitomokia~~ *Matakarua*

Assign AV8(Pupuke,Onepoto) to North Head. *Must follow Mono Lake*

Assign AV10 to Mt Victoria

Assign AV7 to Hopua. *Hopua is allowed to fall within an excursion.*

Stratigraphy places it after Crater Hill, and before Puketutu.

.....

Assign AV15,17 to Pigeon Mountain, ~~Robertson Hill~~ *Little Rangitoto*

Assign AV22 to ~~Matakarua~~ *Styaks Swamp*

.....

Revised Monte Carlo Ordering Algorithm

- Wiri Mountain and Puketutu assigned ages from Normal distribution (within ML excursion)
- Remaining ML events assigned ages from a Uniform distribution, width 1 ka
  - Taylor's Hill either oldest or youngest of ML events
  - 35 events with est. ages and errors assigned an age from a Normal distribution.
  - Otara Hill and Hampton Park within 0.1 ka
  - Mt Cambria ~ Mt Victoria.
- Otuataua = Maungataketake - U(0,0.1) ka.
- Sample 1ka Lashamp excursion from N(40.4,1.1)
  - If overlaps Maungataketake/Otuataua, resample all 3
- If sampled ages violate the stratigraphy, redo
  - NOTE: Tephra matches generate additional implied stratigraphy.

Tank Farm, Onepoto, St Heliers, Orakei Basin, Hopua, Pukaki, Kohuora, Little Rangitoto, Pukeiti

- No events except those in D can occur among ML events, during Lashamp, between Otuataua and Maungataketake, or between Otara Hill and Hampton Park
- Remaining 8 events assigned age uniform between any upper and lower stratigraphic bounds, etc ...

Changes in order?

Name	Mean Age	Age Error
.....	.....	.....
Little Rangitoto	92.3	57.7
.....	.....	.....
Maungataketake	41.4	0.4
One Tree Hill	37.4	0.7
Motukorea	36.1	0.9
Mt Albert	35.2	0.9
Kohuora	35.1	1.0
Crater Hill	34.1	0.3
Hopua Basin	33.6	0.4
Puketutu	33.0	0.5
North Head	32.9	0.4
Hampton Park	32.4	4.8
Panmure Basin	32.3	0.3
Taylors Hill	32.0	1.9
Mt Roskill	32.0	1.9
Ash Hill	31.8	0.2
.....	.....	.....
Wiri Mountain	30.9	0.4
Mt Richmond	29.9	0.6
Three Kings	28.8	0.3
Mt Eden	28.4	0.3
Waitomokia	28.1	0.8
.....	.....	.....
Otara Hill	25.9	0.7
Pukeiti	22.3	4.2
.....	.....	.....
Otuataua	16.4	4.3
.....	.....	.....
Matakarua	15.1	0.7
.....	.....	.....

`C14' Order

`Magnetic' Order

Name	Mean Age	Age Error
.....	.....	.....
Waitomokia	200.2	54.3
.....	.....	.....
Pukeiti	122.5	56.1
.....	.....	.....
Maungataketake	41.5	0.4
Otuataua	41.4	0.4
One Tree Hill	36.6	0.8
Motukorea	35.3	0.8
Kohuora	34.0	0.3
Mt Albert	33.5	0.7
Ash Hill	32.4	0.1
Crater Hill	32.0	0.2
Wiri Mountain	32.0	0.3
Hopua Basin	31.9	0.3
Mt Richmond	31.8	0.3
Taylors Hill	31.8	0.3
Puketutu	31.7	0.3
.....	.....	.....
North Head	31.4	0.1
Panmure Basin	31.4	0.1
.....	.....	.....
Three Kings	28.9	0.3
Mt Eden	28.5	0.3
Mt Hobson	28.1	0.4
Matakarua	27.8	0.6
Pigeon Mt	27.7	0.4
Little Rangitoto	27.2	0.4
Mangere Lagoon	26.7	0.4
Hampton Park	25.9	0.7
Otara Hill	25.9	0.7
.....	.....	.....

Excursion events within 100 years?

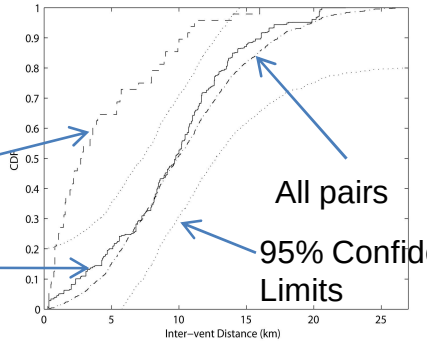
Ash Hill	32.0	0.1
Crater Hill	31.9	0.1
Wiri Mountain	31.9	0.1
Hopua Basin	31.9	0.1
Mt Richmond	31.9	0.1
Taylors Hill	31.9	0.1
Puketutu	31.9	0.1
North Head	31.8	0.1

Spatio-temporal Structure?

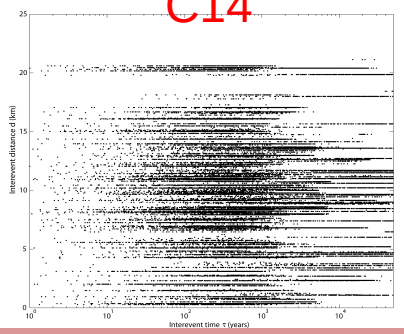
1000 Monte Carlo repetitions: no spatial clustering between sequential events (top); no correlation between interevent time and distance (bottom)

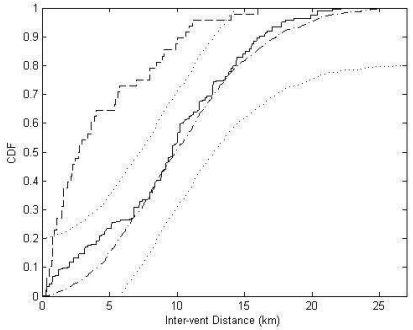
Allen & Smith (1994) ordering

MonteCarlo ordering

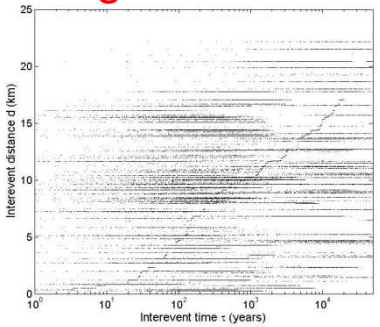


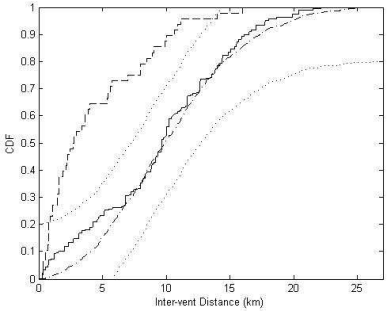
`C14'



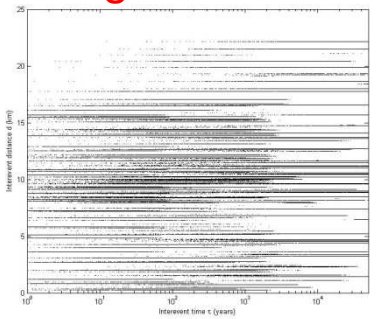


`Magnetic, 1ka'





`Magnetic 0.1ka'

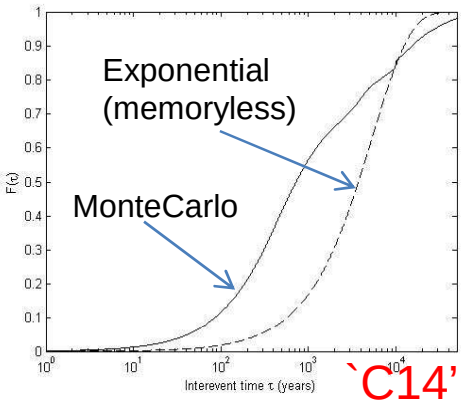


Conclusion: Independent temporal and spatial terms justified in model

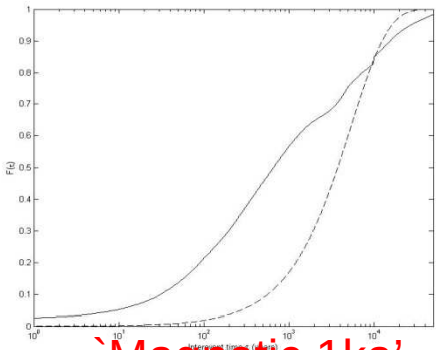
Time-Varying Eruption Rate

1000 Monte Carlo repetitions, kernel smoothing

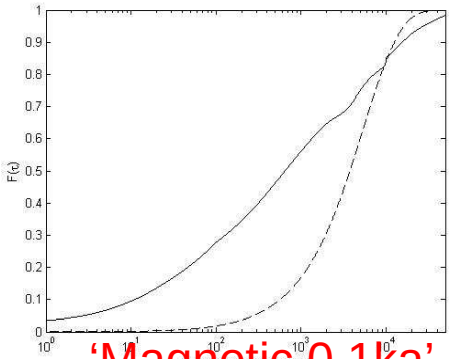
excess of both short and long reposes
- 'self-exciting' model



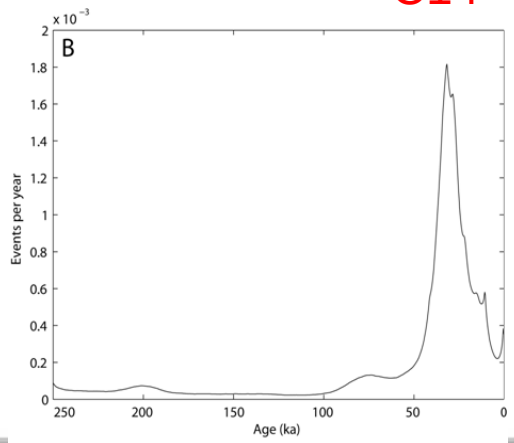
`C14'

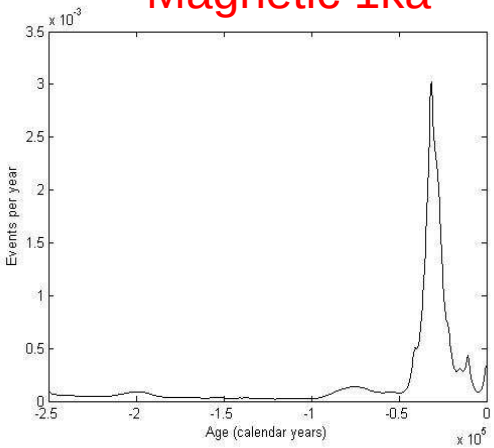


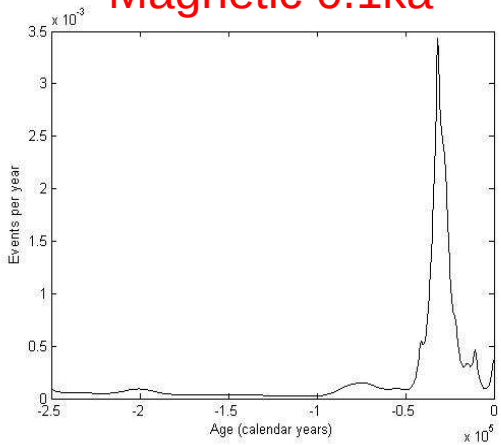
`Magnetic 1ka'



'Magnetic 0.1ka'



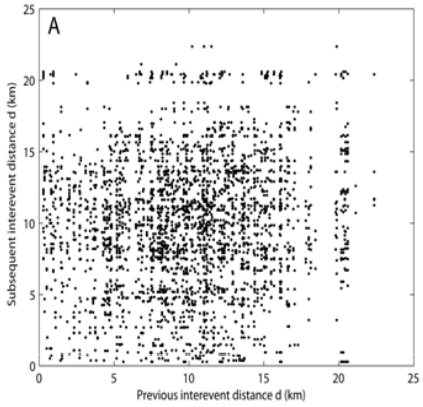




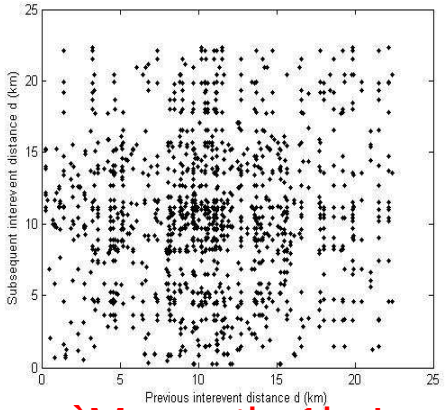
Spatial Structure, Second Order Analysis

1000 Monte Carlo repetitions, sequential pair azimuths show tendency to AVOID alignments

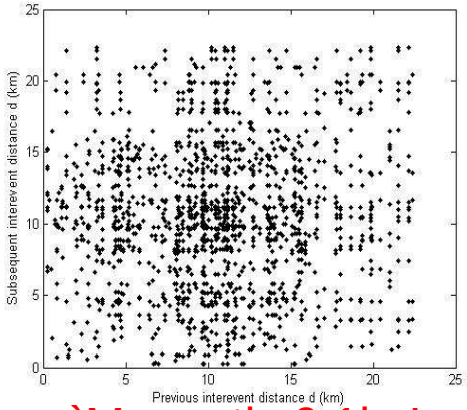
Successive vent-vent distances



`C14'

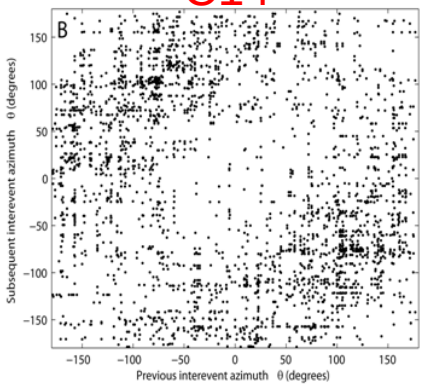


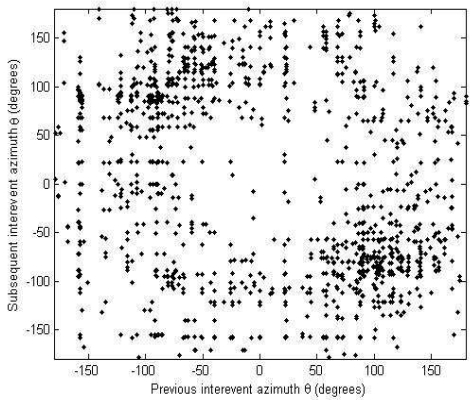
`Magnetic 1ka'

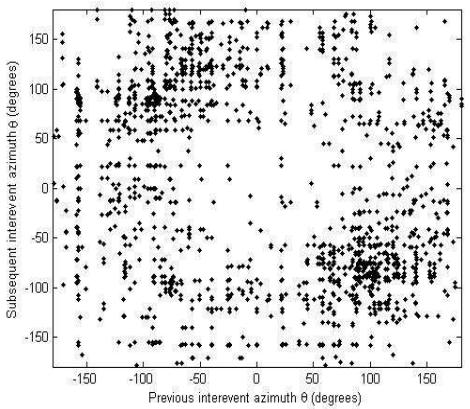


`Magnetic 0.1ka'

Successive vent-vent azimuths

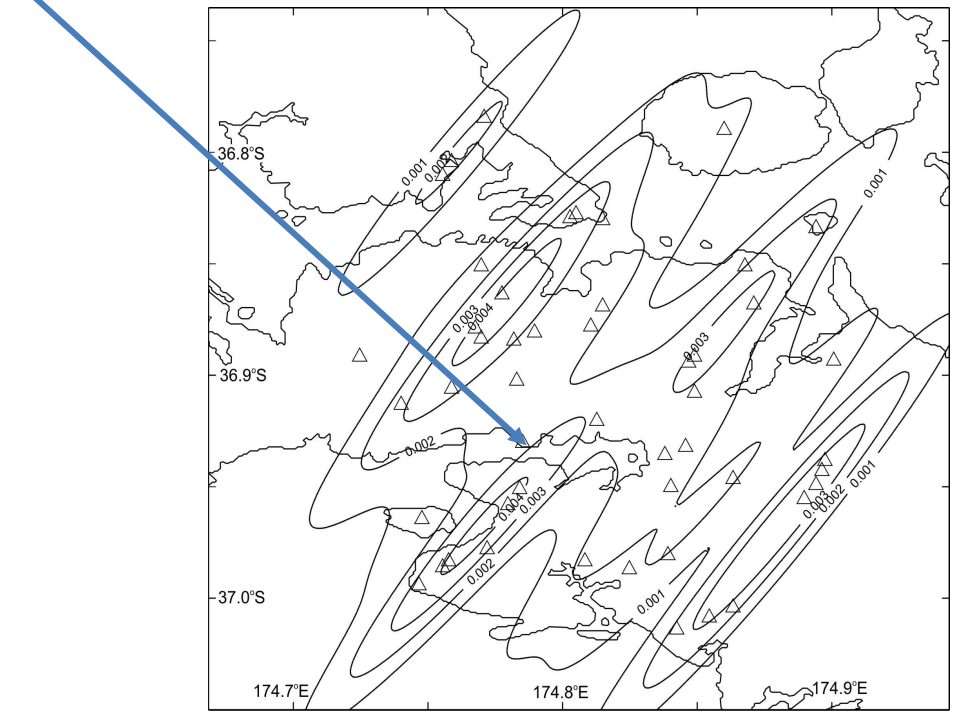






Spatial Likelihood

- **Kernel estimate of spatial probability (Connor and Connor 2009)**
  - **Ruaumoko location not relatively unlikely ☺**



Conclusions

- Paleomagnetism contradicts C14 ages
- Paleomagnetism during an excursion should be more reliable than C14
  - How tight are the resulting constraints?
  - Other excursions?
- Spatio-temporal independence is unaffected by the change from C14 to paleomagnetism,
  - although the ordering changes, as do a number of other estimated ages.

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