# A Bayesian Belief Network for a retrospective analysis of the 1976 Guadeloupe volcanic crisis

# Elicitation findings[1]

**Summary**
This elicitation exercise demonstrates clearly that considerable uncertainty attends nearly every aspect involved in assessing the (hidden internal) states of the volcano from observational information and data, and that the diagnostic power of such indications is generally weak (and would have been in 1976….). That said, the exercise now allows us to put the related scientific uncertainty into more quantitative terms.

By and large, the responses to the target items are reasonably coherent across the group, but the wide spreads in credible intervals tend to mask any systematic differences between Experts, where these exist.

The Facilitator's comments are included below each item range graph plot where certain discrepancies or other concerns seem to emerge.

**Notes to the elicitation**
Three target items (out of the 62 in total) stand out as meriting further discussion:

1] Target Item 11 (Q12 on questionnaire) concerns false positives for $SO_2$ detection. Some colleagues indicate no information whatsoever in this regard, but others suggest there is some non-zero chance of it having evidential worth, albeit very small.

2] Target Item 36 (Q26 row 4 on table): four experts seem convinced there is a good probability of seeing shallow VTs when the hydrothermal system is perturbed by deep magma action but magma is NOT ascending; the other three are much more cautious and go for lower probability values.

3] Target Items 51 & 52 (Q27 two rows on table): two Experts (2 & 3) diverge from colleagues on the questions of No_eruption or Phreatic eruption probabilities when hydrothermal system is perturbed by deep magmatic action but magma is not ascending. As this echoes point 2 above, issues about this particular state of the volcano, and its implications, merit further discussion.

In the range graph plots provided for each target item, two Decision Maker (DM) solutions are displayed: the line labelled "Eq wts" is the solution obtained when all experts are given the same weight, whilst "Fac wts" denotes a sensitivity test using weights ascribed to each expert by the

[1] Notes prepared by facilitator (WPA) immediately after elicitation responses were processed.

Facilitator on the basis of their experience and knowledge of Guadeloupe. The ratio of the highest weight to lowest in this case is about 4.5 – *i.e.* the "best" expert is nearly five times more influential than the least, under this regime. That said, differences between the "Eq wts" and "Fac wts" solutions are generally very small.

Some of the item credible intervals span orders of magnitude, so the DM is computed on a log scaling for a number of items (indicated in range graph headers). Because zero is not allowed in a log world, the value of 1e-6 is assumed as the default minimum probability (some colleagues go below this on particular items, however).

**Summary of pooled Decision Maker (DM) quantile solutions with experts given equal weights**

| Item | ID | scale | 5%ile | 50%ile | 95%ile | Description |
|---|---|---|---|---|---|---|
| 1 | Magmatic unrest | log | 7.6E-5 | 0.08 | 0.81 | Pr [deep magmatic agitation] |
| 2 | VTs no_unrest | log | 4.8E-7 | 0.00086 | 0.067 | Pr [VTs \| no deep agitation] |
| 3 | VTs unrest | UNI | 0.039 | 0.50 | 0.92 | Pr [VTs \| deep agitation] |
| 4 | Deform no_unrest | log | 2.2E-7 | 6.1E-6 | 0.18 | Pr [Deformation \| no deep agitation] |
| 5 | Deform unrest | log | 6.7E-5 | 0.73 | 0.99 | Pr [Deformation \| deep agitation] |
| 6 | Tilt no_unrest | UNI | 0.11 | 0.75 | 0.9942 | Pr [BubbleTilt \| no deep agitation] |
| 7 | Tilt unrest | UNI | 0.35 | 0.82 | 0.9958 | Pr [BubbleTilt \| deep agitation] |
| 8 | DryT no_unrest | log | 0.00018 | 0.081 | 0.38 | Pr [DryTilt \| no deep agitation] |
| 9 | DryT unrest | UNI | 0.16 | 0.64 | 0.95 | Pr [DryTilt \| deep agitation] |
| 10 | Magma ascends | log | 0.0014 | 0.10 | 0.67 | Pr [Magma ascending \| deep magmatic agitation] |
| 11 | SO2 \| noascent | UNI | 0.14 | 0.50 | 0.70 | Pr [SO2 detected \| magma not ascending] |
| 12 | SO2 \| ascends | UNI | 0.17 | 0.69 | 0.94 | Pr [SO2 detected \| magma is ascending] |
| 13 | Glass \| noascent | log | 3.5E-5 | 0.16 | 0.49 | Pr [Fresh glass \| magma not ascending] |
| 14 | Glass \| ascend | UNI | 0.30 | 0.79 | 0.98 | Pr [Fresh glass \| magma is ascending] |
| 15 | Trem \| nohydrtherm | log | 1.6E-5 | 0.031 | 0.27 | Pr [Tremor \| hydrotherm not disturbed] |
| 16 | Trem \| hydrtherm | UNI | 0.31 | 0.83 | 0.9958 | Pr [Tremor \| hydrotherm is disturbed] |
| 17 | LoVT \| nounrest | UNI | 0.52 | 0.88 | 0.99 | Pr [low VT rate \| no deep magmatic agitation] |
| 18 | ModVT \| nounrest | UNI | 0.0074 | 0.10 | 0.34 | Pr [mod VT rate \| no deep magmatic agitation] |
| 19 | HiVT \| nounrest | log | 1.8E-6 | 0.0096 | 0.12 | Pr [high VT rate \| no deep magmatic agitation] |

| | | | | | | |
|---|---|---|---|---|---|---|
| 20 | LoVT \| unrest | log | 1.8E-6 | 0.020 | 0.34 | Pr [low VT rate \| deep magmatic agitation] |
| 21 | ModVT \| unrest | UNI | 0.12 | 0.44 | 0.88 | Pr [mod VT rate \| deep magmatic agitation] |
| 22 | HiVT \| unrest | UNI | 0.082 | 0.56 | 0.95 | Pr [high VT rate \| deep magmatic agitation] |
| 23 | LoFelt \| nounrest | UNI | 0.43 | 0.92 | 0.9989 | Pr [low Felt rate \| no deep magmatic agitation] |
| 24 | ModFelt \| nounres | log | 0.00027 | 0.063 | 0.52 | Pr [mod Felt rate \| no deep magmatic agitation] |
| 25 | HiFelt \| nounrest | log | 2.0E-7 | 0.00042 | 0.050 | Pr [high Felt rate \| no deep magmatic agitation] |
| 26 | LoFelt \| unrest | log | 3.5E-6 | 0.069 | 0.34 | Pr [low Felt rate \| deep magmatic agitation] |
| 27 | ModFelt \| unrest | UNI | 0.12 | 0.43 | 0.83 | Pr [mod Felt rate \| deep magmatic agitation] |
| 28 | HiFelt \| unrest | UNI | 0.10 | 0.50 | 0.87 | Pr [high Felt rate \| deep magmatic agitation] |
| 29 | Hydtherm \| ascent | UNI | 0.90 | 0.9995 | 1 | Pr [hydrothermal perturbed \| magma ascent] |
| 30 | Hydtherm \| unrest | UNI | 0.054 | 0.56 | 0.81 | Pr [hydrothermal perturbed \| deep magmatic agitation] |
| 31 | Fum \| nodeepHydT | log | 3.0E-5 | 0.035 | 0.39 | Pr [fumarole changes \| HydroT not perturbed by deep magmatic agitation] |
| 32 | Fum \| deepHydT | UNI | 0.071 | 0.68 | 0.96 | Pr [fumarole changes \| HydroT perturbed by deep magmatic agitation] |
| 33 | 24VT \| FFF | log | 3.0E-6 | 0.019 | 0.18 | |
| 34 | 24VT \| FTF | UNI | 0.54 | 0.80 | 0.989 | |
| 35 | 24VT \| FTT | UNI | 0.67 | 0.92 | 0.999 | |
| 36 | 24VT \| TFF | log | 0.0014 | 0.46 | 0.84 | |
| 37 | 24VT \| TTF | UNI | 0.68 | 0.88 | 0.995 | |
| 38 | 24VT \| TTT | UNI | 0.85 | 0.97 | 1 | |
| 39 | Erupt \| FFF_No erupt | UNI | 0.91 | 0.996 | 1 | |
| 40 | Erupt \| FFFPhreat | log | 2.4E-6 | 0.0028 | 0.063 | |
| 41 | Erupt \| FFFMagmatic | log | - | - | - | |
| 42 | Erupt \| FFFBlast | log | - | - | - | |
| 43 | Erupt \| FTF_No erupt | UNI | 0.0034 | 0.32 | 0.81 | |
| 44 | Erupt \| FTFPhreat | log | 1.2E-5 | 0.058 | 0.40 | |
| 45 | Erupt \| FTFMagmatic | UNI | 0.057 | 0.35 | 0.72 | |
| 46 | Erupt \| FTFBlast | UNI | 0.038 | 0.29 | 0.79 | |
| 47 | Erupt \| FTT_No erupt | UNI | 0.034 | 0.51 | 0.87 | |

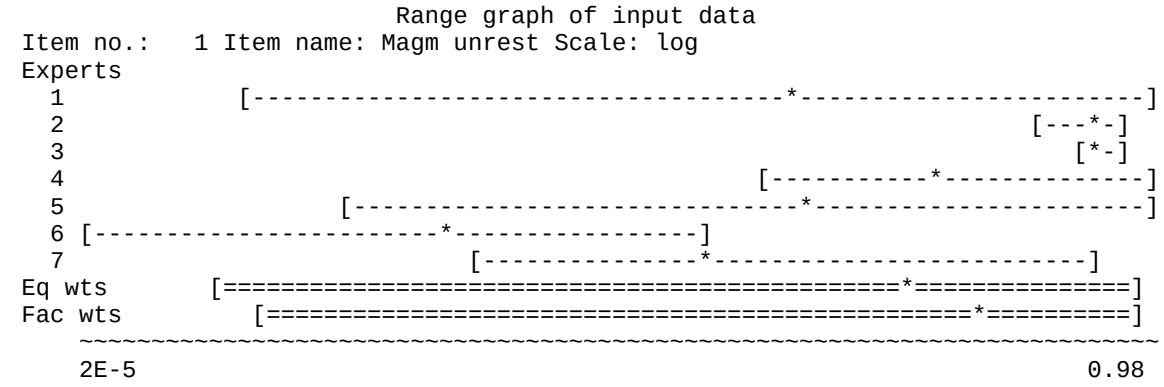
| | | | | | | |
|---|---|---|---|---|---|---|
| 48 | Erupt \| FTTPhreat | UNI | 0.068 | 0.29 | 0.58 | |
| 49 | Erupt \| FTTMagmatic | UNI | 0.0035 | 0.13 | 0.60 | |
| 50 | Erupt \| FTTBlast | log | 1.9E-5 | 0.043 | 0.74 | |
| 51 | Erupt \| TFF_No erupt | UNI | 0.62 | 0.91 | 0.998 | |
| 52 | Erupt \| TFFPhreat | UNI | 0.0023 | 0.054 | 0.50 | |
| 53 | Erupt \| TFFMagmatic | log | 4.4E-8 | 6.5E-6 | 0.0096 | |
| 54 | Erupt \| TFFBlast | log | 1.2E-7 | 7.5E-6 | 0.0075 | |
| 55 | Erupt \| TTF_No | log | 2.8E-5 | 0.39 | 0.98 | |
| 56 | Erupt \| TTFPhr | UNI | 0.013 | 0.15 | 0.45 | |
| 57 | Erupt \| TTFMag | UNI | 0.0027 | 0.17 | 0.68 | |
| 58 | Erupt \| TTFBlast | UNI | 0.0025 | 0.14 | 0.84 | |
| 59 | Erupt \| TTT_No | UNI | 0.0072 | 0.14 | 0.79 | |
| 60 | Erupt \| TTTPhr | UNI | 0.052 | 0.27 | 0.60 | |
| 61 | Erupt \| TTTMag | UNI | 0.0074 | 0.27 | 0.70 | |
| 62 | Erupt \| TTTBlast | UNI | 0.0060 | 0.20 | 0.79 | |

**Prior probability estimate for magmatic intrusion at depth**

1. What is the baseline probability that there is magmatic intrusion at depth?

Probability estimate

| | 5 %ile | 50%ile | 95%ile |
|---|---|---|---|
| Magmatic unrest | 7.6e-5 | 0.080 | 0.81 |



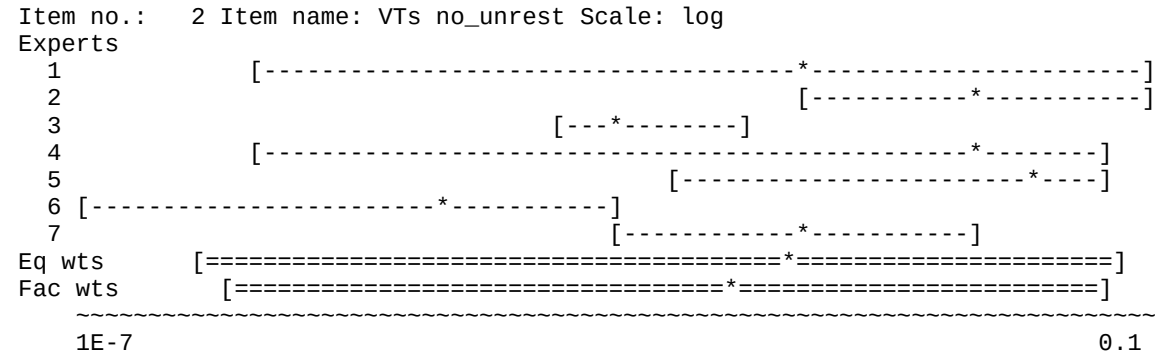

**Facilitator's comments:** probability is very uncertain; two notable high values with strong confidence (Experts 2 & 3)

**Deep Seismicity caused by magmatic intrusion/unrest**
Probability of observing 24 or more (exceeding 2x baseline rate) VT earthquakes per month, and at least 1 felt VT earthquake, over a three month period (so a total of >72 VTs)

2. What is the probability of observing >24 VTs/month and 1 or more felt earthquakes in a three month period given that there is **no magmatic intrusion** at depth?

Probability estimate

| 5 %ile | 50%ile | 95%ile |
|---|---|---|
| 4.5e-7 | 8.6e-4 | 0.067 |

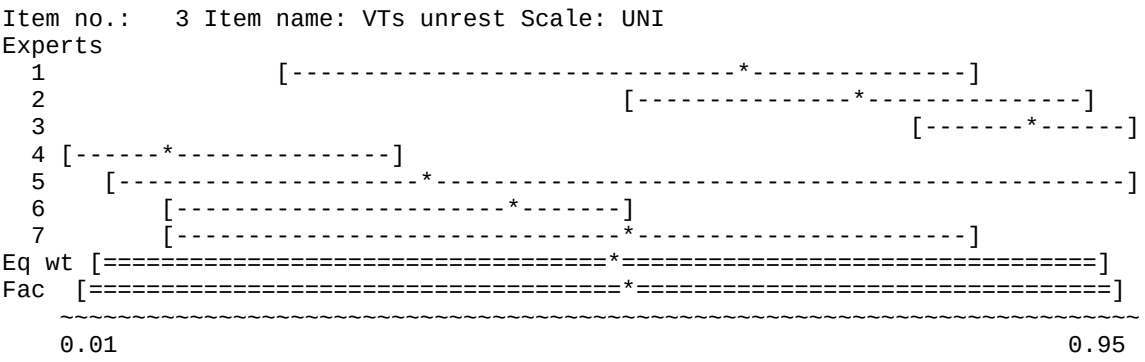



**Facilitator's comments:** none

3. What is the probability of observing >24 VTs/month and 1 or more felt earthquakes in a three month period, given that there is **magmatic intrusion/unrest** at depth?

| 5 %ile | 50%ile | 95%ile |
|---|---|---|
| 0.04 | 0.5 | 0.92 |

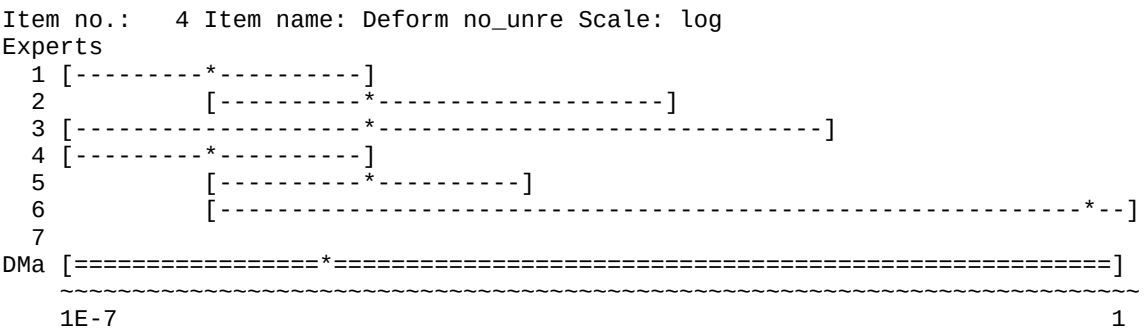
Very low probability tectonic eq.
Regional fault system. High pressure/stress hydrothermal system. Fluid pressure?
Possible – in a state of unrest all or most of the time?




**Facilitator's comments:** wide credible range; suggestion of "two schools of thought", reflected by central prob. value of 0.5

**Ground deformation**
Does the volcano produce a deformation field such that if it were observed would be interpreted as being due to a deep source? Deep source -> wide field deformation. Deep = >5km. Can't think of any non-magmatic processes that could lead to deep source deformation?
4. What is the probability of ground deformation from a deep source in La Soufrière region, given there is **no magmatic intrusion/unrest** at depth?

| Probability estimate | | |
|---|---|---|
| 5 %ile | 50%ile | 95%ile |
| 2.2e-7 | 6.1e-6 | 0.18 |

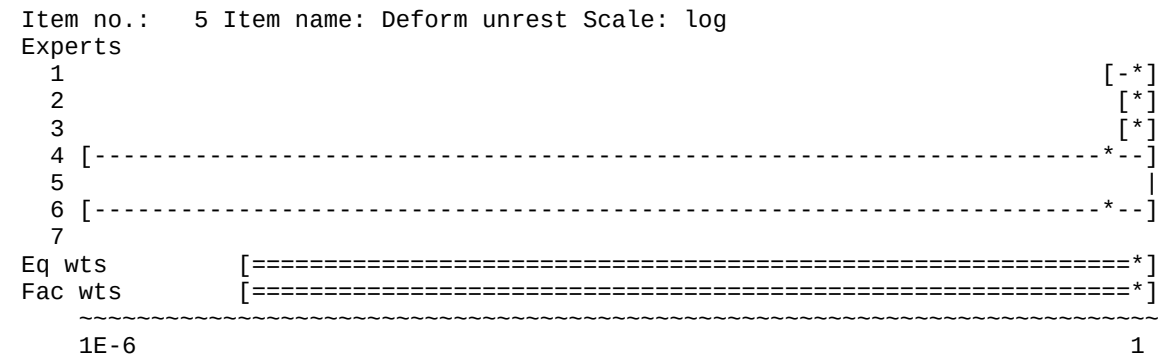



**Facilitator's comments:** Expert 6 disagrees markedly!!

5. What is the probability of ground deformation from a deep source in La Soufrière region, given there is **magmatic intrusion/unrest** at depth?

| 5 %ile | 50%ile | 95%ile |
|---|---|---|
| 7e-5 | 0.73 | 0.99 |

Magma chamber pressurizing – not necessarily any magma ascent.




**Facilitator's comments:** Experts 4 & 6 long-tailed

**Borehole type tiltmeter observations**

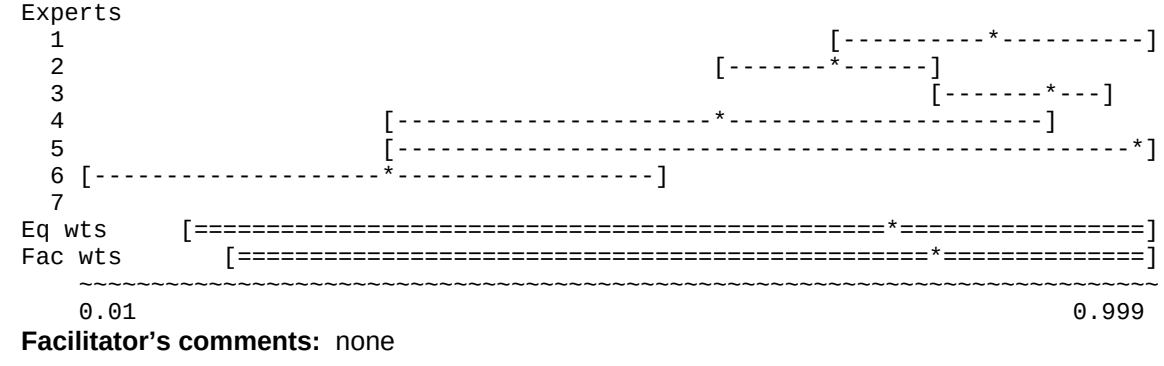
Note these instruments were not installed in boreholes, and there is significant noise in the data.
Tilt observations are defined as either high (> 10 μrad/day) or low (≤10 μrad/day).
Very unreliable and not very informative data. High tilt measurements due to noise (most of the time).
New, unproven technology.

6. What is the probability of measuring **high tilt** (> 10 μrad/day) given that there is **no deep source ground deformation**?

Probability estimate

| | 5 %ile | 50%ile | 95%ile |
|---|---|---|---|
| High tilt | 0.11 | 0.75 | 0.994 |

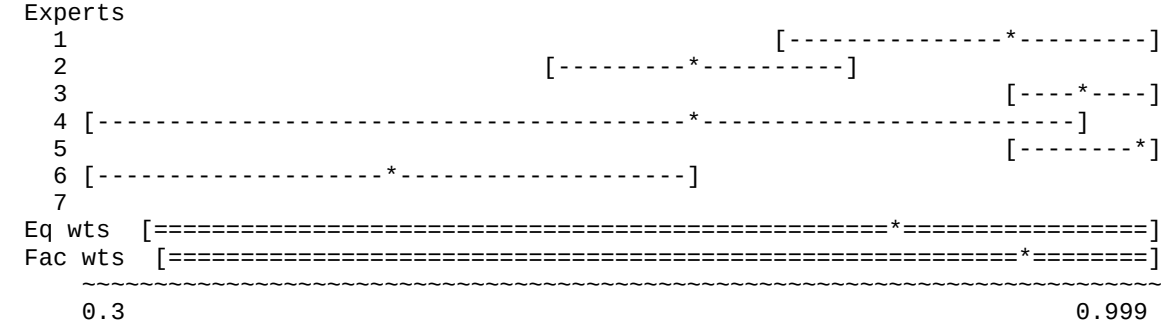
Other causes of tilt
- fault movement/regional tectonics?
- ground instability?




**Facilitator's comments:** none

7. What is the probability of measuring **high tilt** given that there is **deep source ground deformation**?

| | 5 %ile | 50%ile | 95%ile |
|---|---|---|---|
| High tilt | 0.35 | 0.82 | 0.996 |

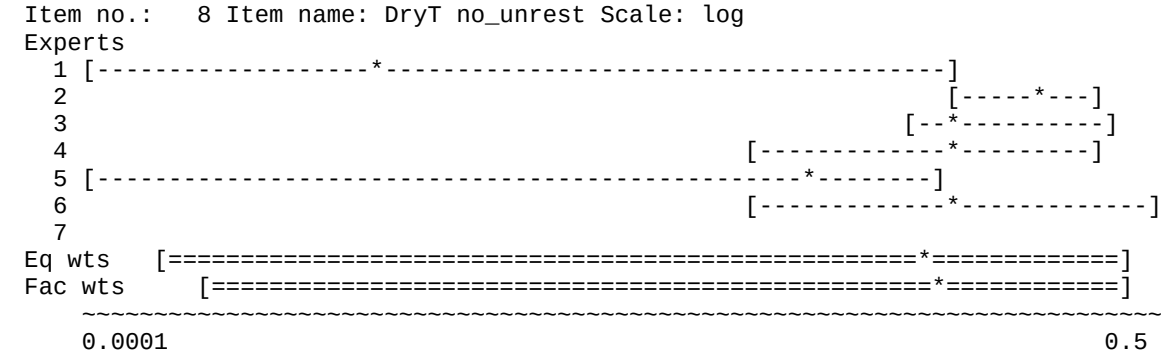



**Facilitator's comments:** some bipartisan behaviour – Eq wts DM central value doesn't reflect anyone's view!!

**Dry tilt observations**

8. What is the probability of measuring **high tilt** (>10 μrad/day) given that there is **no deep source ground deformation**?

| | Probability estimate | | |
|---|---|---|---|
| | 5 %ile | 50%ile | 95%ile |
| High tilt | 0.0002 | 0.081 | 0.38 |

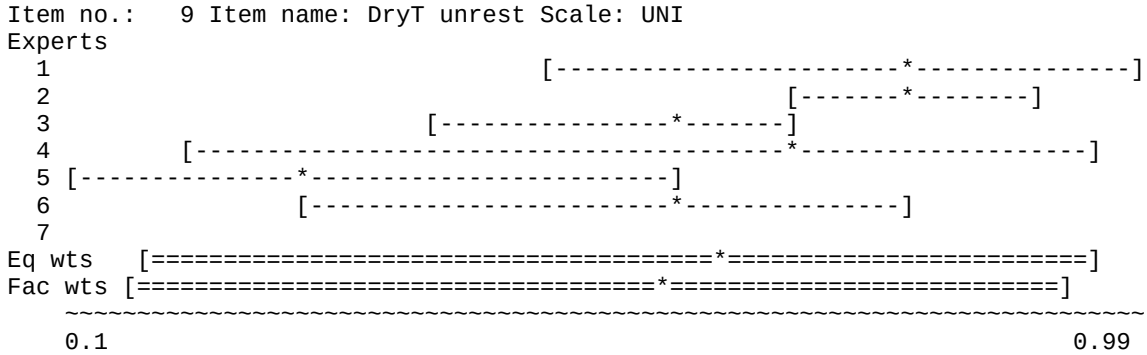



**Facilitator's comments:** Experts 1& 5 long-tailed

9. What is the probability of measuring high tilt given that there is deep source **ground deformation**?

| | 5 %ile | 50%ile | 95%ile |
|---|---|---|---|
| High tilt | 0.16 | 0.64 | 0.95 |

Accurate, tested method. But no real trend in Guadeloupe data. IF there is deformation relatively high probability of detecting it with dry tilt.



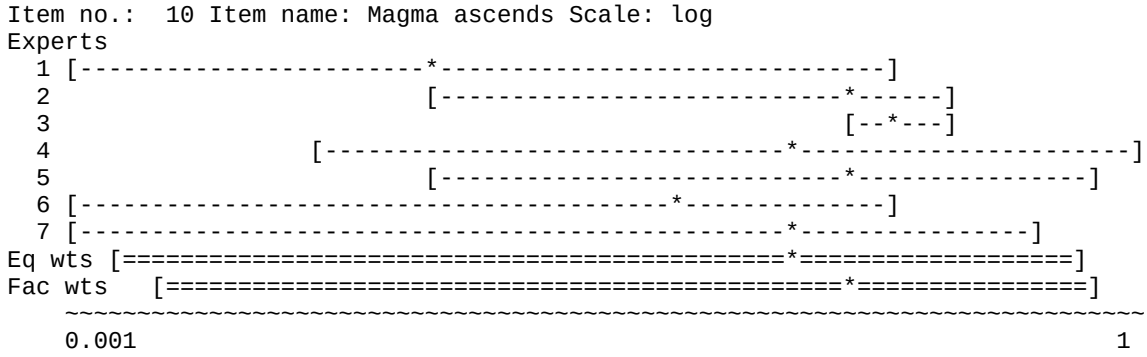

**Facilitator's comments:** scattered values, wide credible interval

**Magma ascent**

11. In a three month period, what is the probability that magma is ascending (in the region 5km below sea level to the near surface), given **magmatic intrusion at depth**? Ascent does not necessarily imply magma will actually reach the surface, it could remain stalled at shallow depth.

Probability estimate

| | 5 %ile | 50%ile | 95%ile |
|---|---|---|---|
| Magma ascent | 0.0014 | 0.10 | 0.67 |



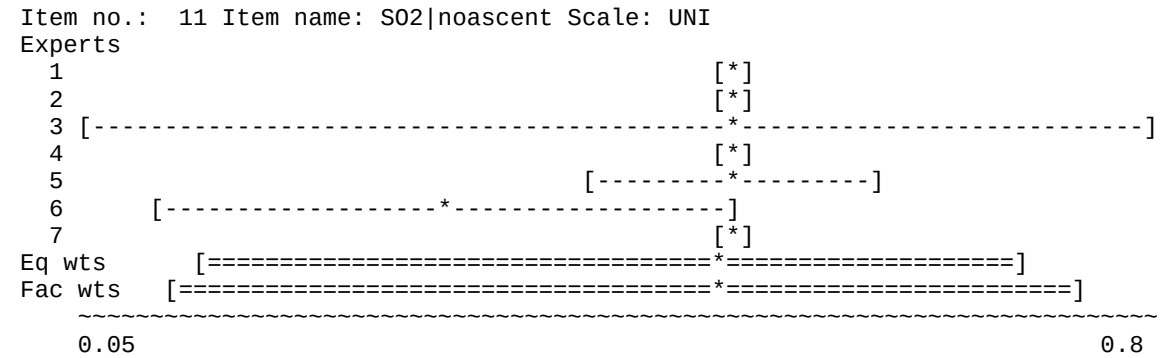

**Facilitator's comments:** wide credible interval

**Gas emissions**

12. What is the probability of detecting $SO_2$ in emissions from La Soufrière, given **magma is not ascending**?
Consider false detection rate, and the probability of $SO_2$ emission due to deep unrest (<5km below sea level) – is this possible?

Probability estimate

| | 5 %ile | 50%ile | 95%ile |
|---|---|---|---|
| $SO_2$ detected | 0.14 | 0.50 | 0.70 |

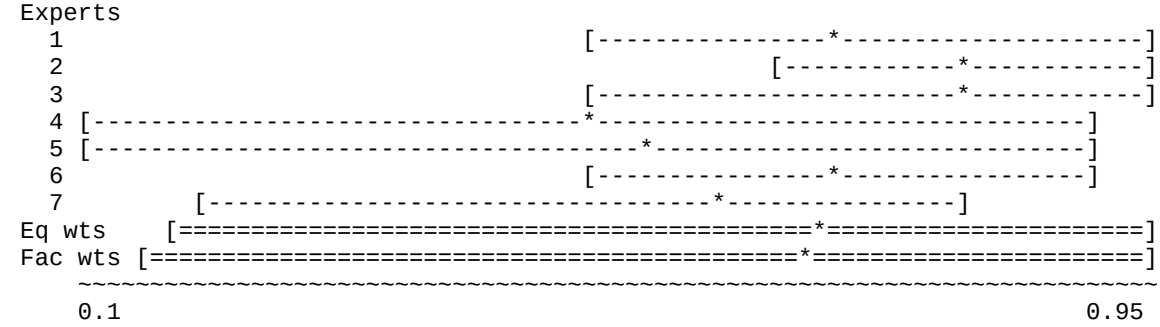



**Facilitator's comments:** several Experts just responded with a single prob. value of 0.5 for this item. Expert 3's distribution suggests he thinks there is a small chance that the false positive rate is below 50%, and Expert 6 clearly thinks so! The issue warrants more discussion.

13. What is the probability of detecting $SO_2$ in emissions from La Soufrière, given **magma is ascending**?

| | 5 %ile | 50%ile | 95%ile |
|---|---|---|---|
| $SO_2$ detected | 0.17 | 0.69 | 0.94 |

No published data (only pH). Gas data very unreliable (contaminated samples, not possible to sample at all fumaroles – main fumarole too dangerous?)




**Facilitator's comments:** none

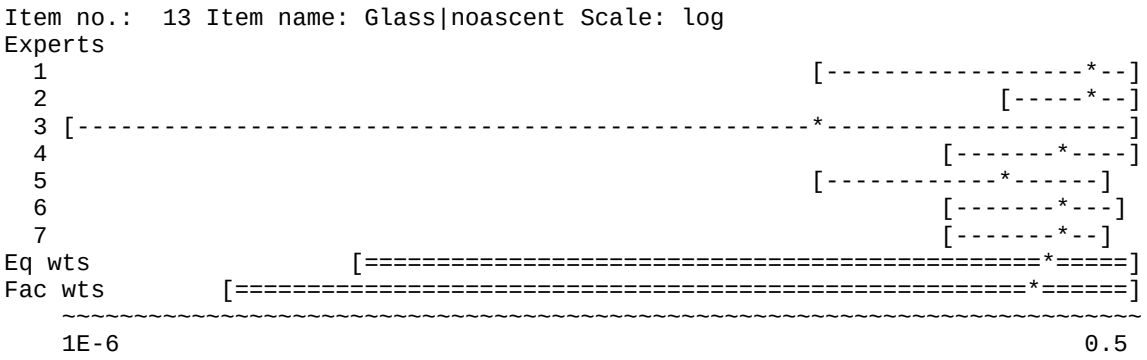
**Petrology**

The observation of fresh glass (unaltered juvenile material) in erupted/ejected material.

It is important to account for misidentification - fresh glass may be present at the surface, but not identified (or captured in the sample), alternatively it might be falsely identified as present. Even if magma is ascending, fresh material might not be present at the surface. If magma is not ascending, there cannot be any new material at the surface, although could have old products, ash etc. remobilised by phreatic activity. In this case we need to consider the probability of misidentification.

14. What is the probability of identifying fresh glass in ash samples from La Soufrière, given **magma is not ascending**?

| | Probability estimate | | |
|---|---|---|---|
| | 5 %ile | 50%ile | 95%ile |
| Fresh glass observed | 3.5e-5 | 0.16 | 0.49 |

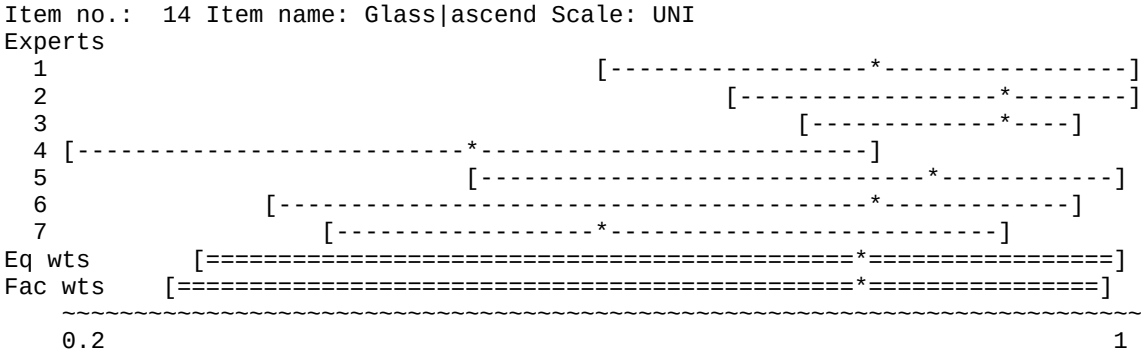



**Facilitator's comments:** Expert 3 has long tailed distribution

15. What is the probability of identifying fresh glass in ash samples from La Soufrière, given **magma is ascending**?

| | 5 %ile | 50%ile | 95%ile |
|---|---|---|---|
| Fresh glass observed | 0.30 | 0.79 | 0.98 |

Probability of seeing glassy components in phreatic ashes? May look like fresh glass, but not actually juvenile material (from pumice etc.?)




**Facilitator's comments:** confidence bands wider and more scattered than for the "expert" in 1976!!

**Tremor**

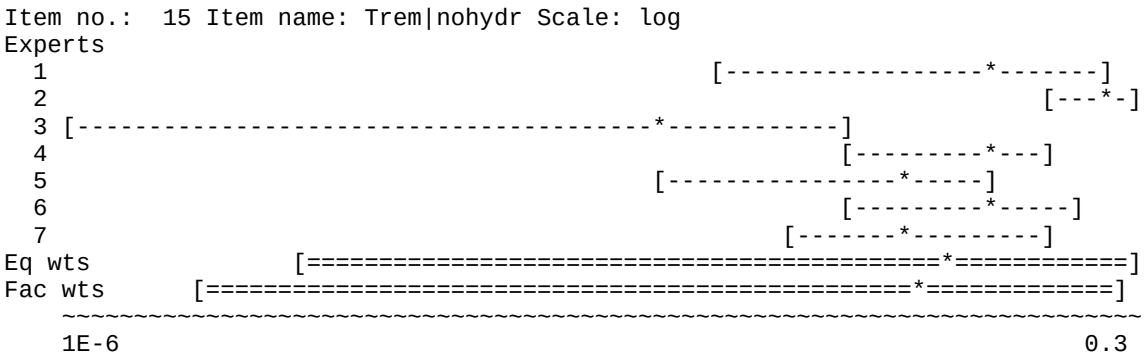
Continuous tremor due to venting
Generated by gas escape/fluid flow?
Tremor episodes very highly correlated with phreatic explosions.
Not very informative w.r.t movement of magma **– change link** to connect from perturbation of hydrothermal system due to magma ascent

16. What is the probability that volcanic tremor will be observed, given **there is no perturbation of the hydrothermal system due to magma ascent**?

Probability estimate

| | 5 %ile | 50%ile | 95%ile |
|---|---|---|---|
| Tremor present | 1.6e-5 | 0.031 | 0.27 |

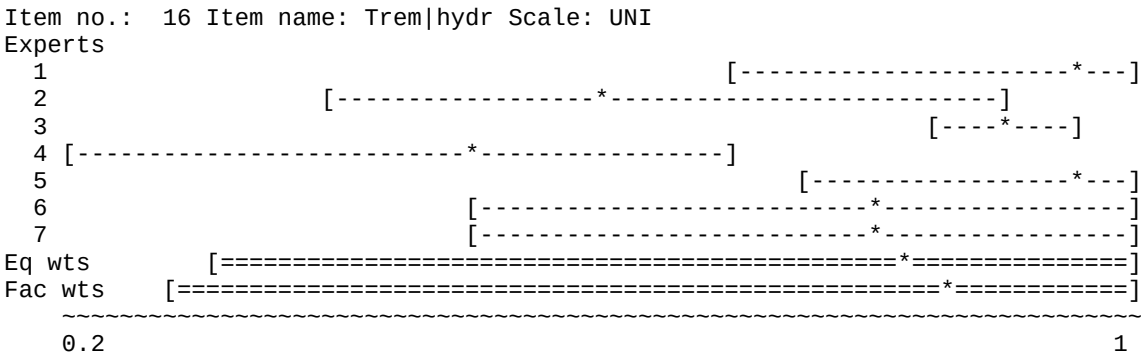
Probability that other processes will perturb the hydrothermal system and result in tremor? E.g. changes in groundwater circulation?




**Facilitator's comments:** Expert 3 again goes deep diving!

17. What is the probability that volcanic tremor will be observed, given there **is a perturbation of the hydrothermal system due to magma ascent**?

| | 5 %ile | 50%ile | 95%ile |
|---|---|---|---|
| Tremor present | 0.31 | 0.83 | 0.996 |




**Facilitator's comments:** none

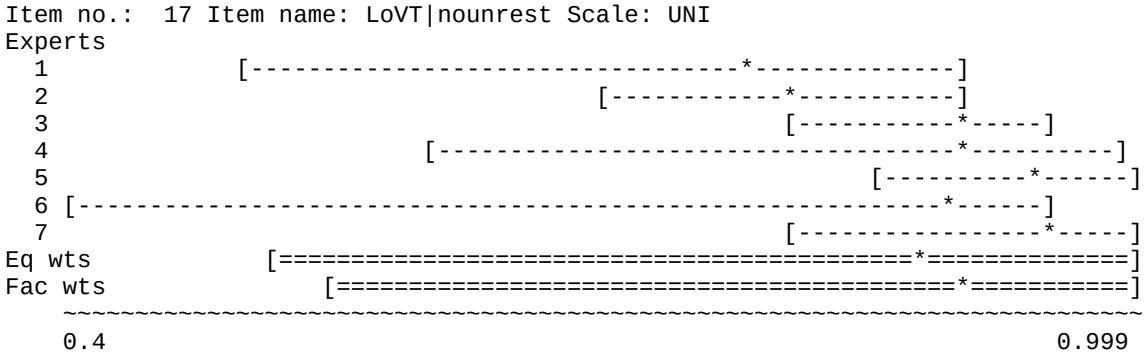
**Recorded VT earthquake rate**

The baseline rate for recorded VT earthquakes for Guadeloupe is approximately 12 per month.
Where $R_{VT}$ = VT earthquake rate per month, states are defined as follows:

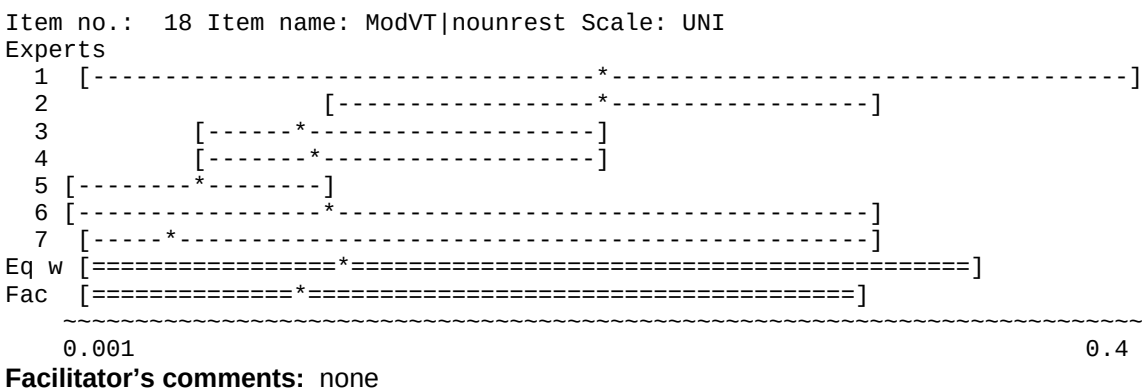
| | |
|---|---|
| Low: $R_{VT} \leq 24$ /month | *up to 2X the baseline rate* |
| Moderate: $24 < R_{VT} \leq 120$ /month | *less than 10 x baseline* |
| High: $R_{VT} > 120$ /month | *greater than 10 x baseline* |

18. What is the probability of observing low, moderate or high rates of VT earthquakes over three months, given that magma is **not INTRUDING**?

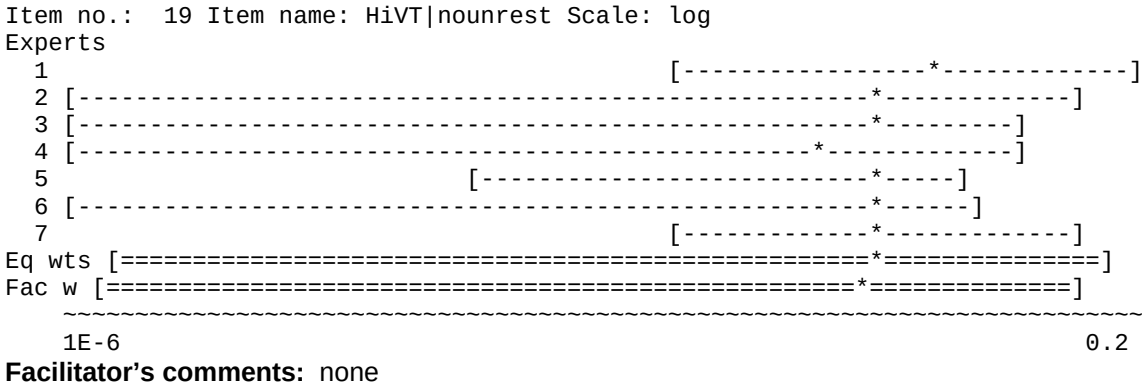
| | Probability estimate | | |
|---|---|---|---|
| | 5 %ile | 50%ile | 95%ile |
| Low observed VT rate | 0.52 | 0.88 | 0.993 |
| Moderate VTs | 0.007 | 0.10 | 0.34 |
| High VTs | 1.8e-6 | 0.0096 | 0.12 |




**Facilitator's comments:** none



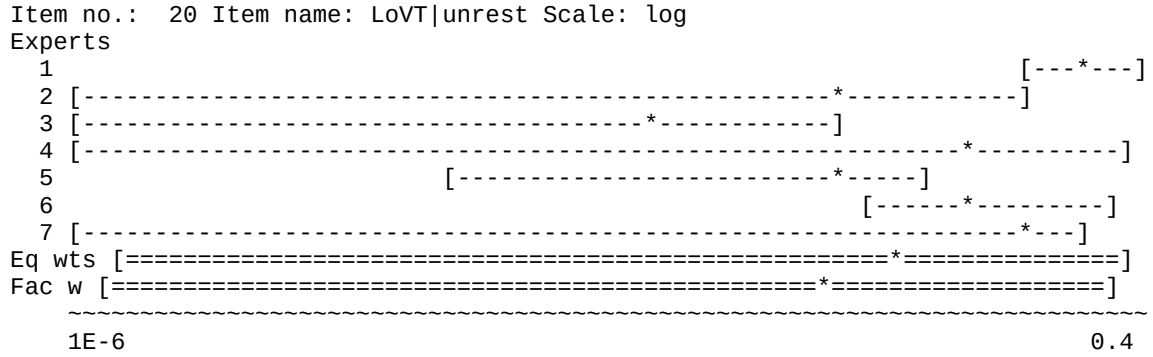

**Facilitator's comments:** none



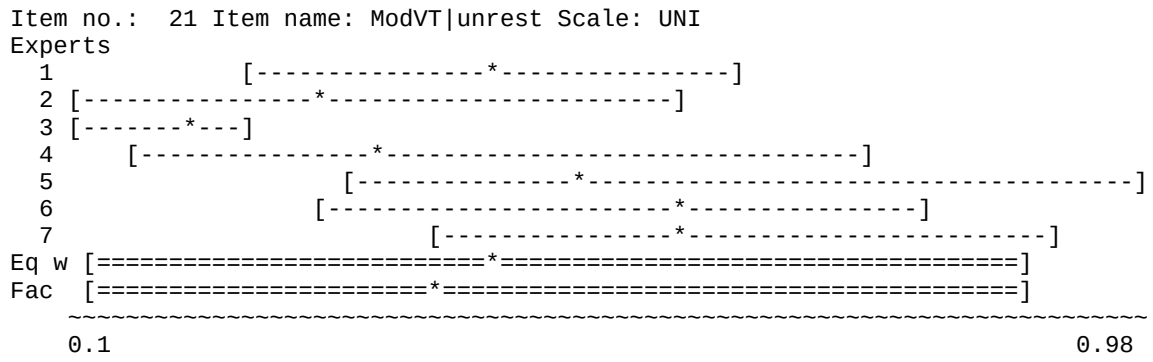

**Facilitator's comments:** none

19. What is the probability of observing low, moderate or high rates of VT earthquakes over three months, given that magma is **INTRUDING**?

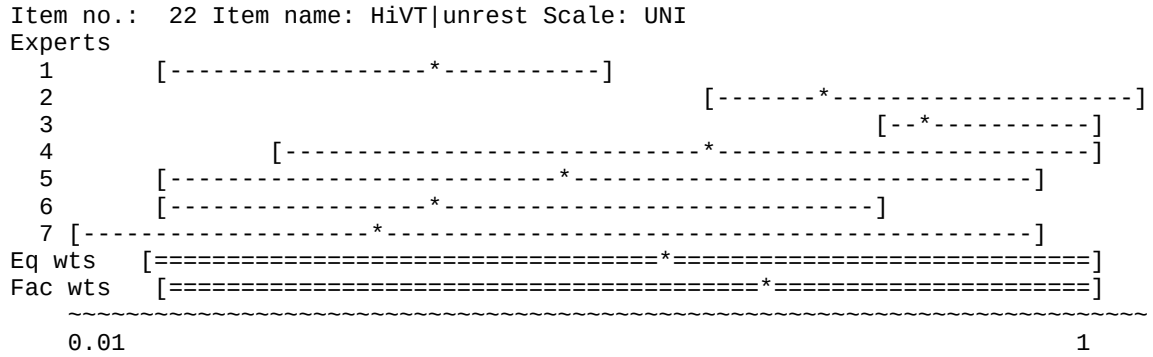
| | 5 %ile | 50%ile | 95%ile |
|---|---|---|---|
| Low observed VTs | 1.8e-6 | 0.020 | 0.34 |
| Moderate VTs | 0.12 | 0.44 | 0.88 |
| High VTs | 0.082 | 0.56 | 0.95 |




**Facilitator's comments:** long tailed distributions




**Facilitator's comments:** none




**Facilitator's comments:** none

**Felt VT earthquake rate**

VT earthquakes with a duration magnitude (Md) of apporximately 2 or greater.
Where $R_{FE}$ = felt VT earthquake rate per year, states are defined as follows:

| | |
|---|---|
| Low: $R_{FE} \leq 1$ /year | *up to the baseline rate* |
| Moderate: $1 < R_{FE} \leq 10$ /year | *less than 10 x baseline* |
| High: $R_{FE} > 10$ /year | *greater than 10 x baseline* |

The baseline rate is approx 1 /year (historic record gives ~0.6/year)

**Notes:**

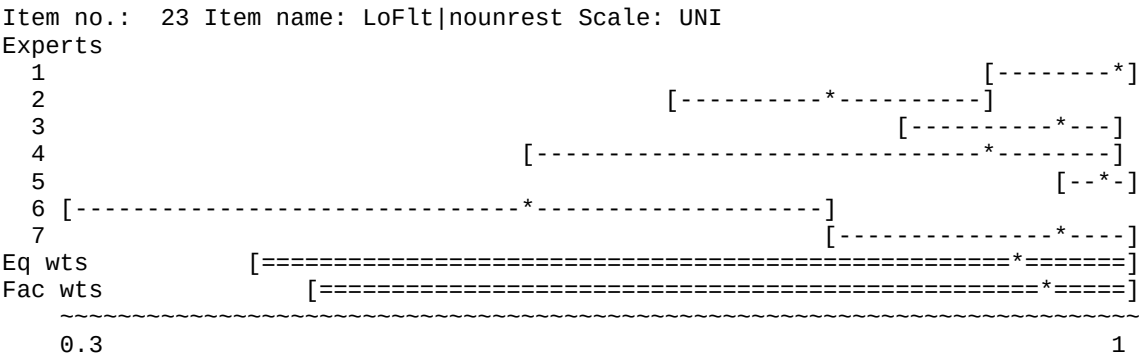
We had/have historical information on numbers etc of felt VT earthquakes in previous episodes of unrest that have been used to inform judgement, and the threshold for feeling events is pretty much a constant (give or

take population distribution, reporting completeness, etc) - so numbers of felt events is a quite stable "parameter"....
The felt VT is also a proxy for overall seismic energy release. In Guadeloupe the duration magnitude and the Gutenberg-Richter laws give the following (for a constant hypocentral distance of 3 km, eg. Parnasse Observatory station):
D = 3 km Md = 2*(Log10(T))+0.0035*D-0.87 E = (10^((2.9+1.92*Md)-0.024*(Md*Md)))/1000000

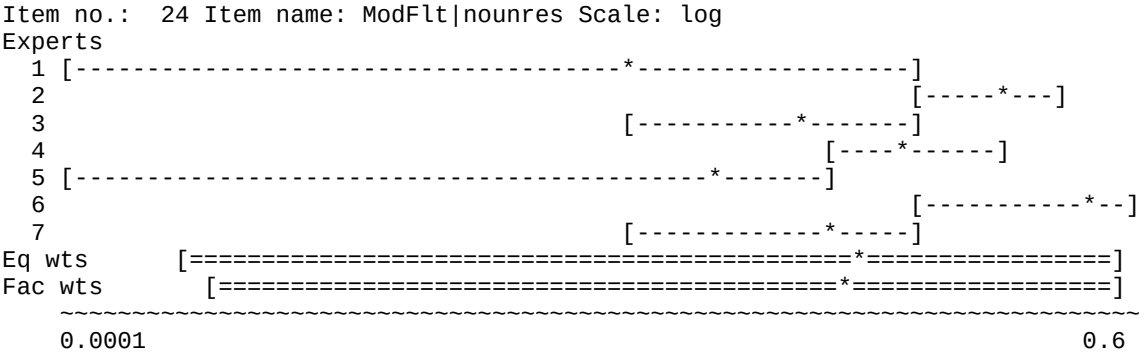
20. What is the probability of low, moderate or high rates of felt VT earthquakes, given **magma is not INTRUDING**?

| | Probability estimate | | |
|---|---|---|---|
| | 5 %ile | 50%ile | 95%ile |
| Low number of felt VTs | 0.43 | 0.92 | 0.999 |
| Moderate felt VTs | 2.7e-4 | 0.063 | 0.52 |
| High felt VTs | 2e-7 | 4.2e-4 | 0.05 |

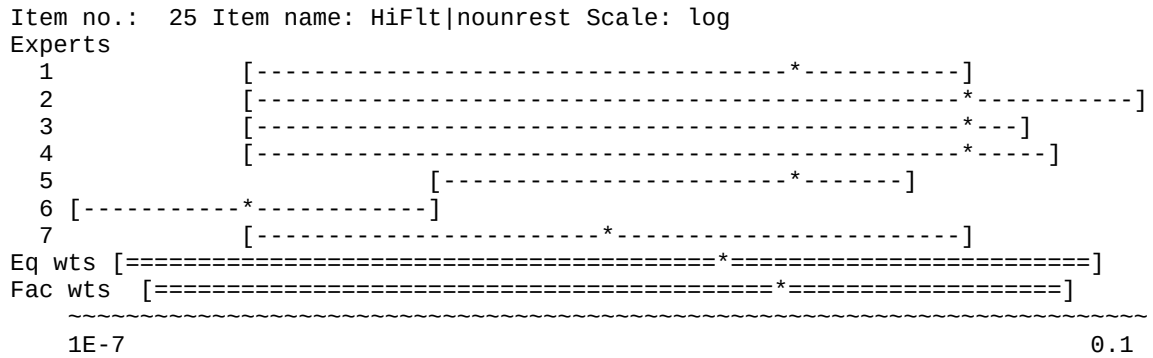
Fault activated? (affect hydrothermal system -> gas, seismics)




**Facilitator's comments:** none




**Facilitator's comments:** none

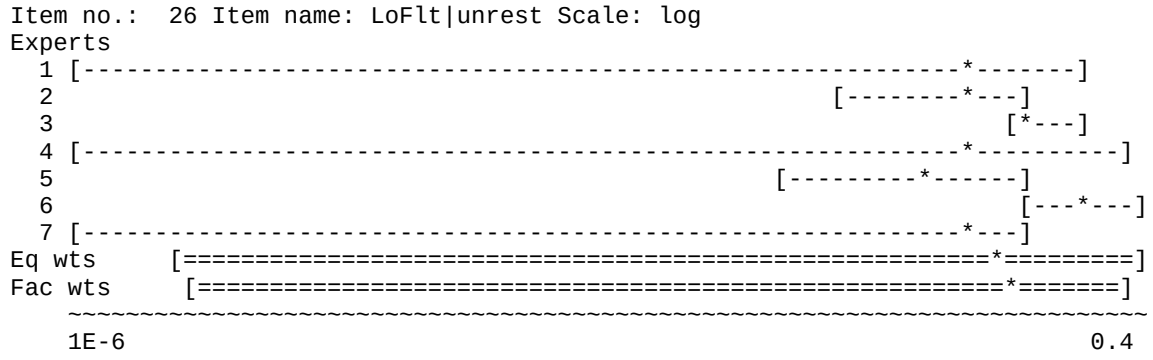



**Facilitator's comments:** none

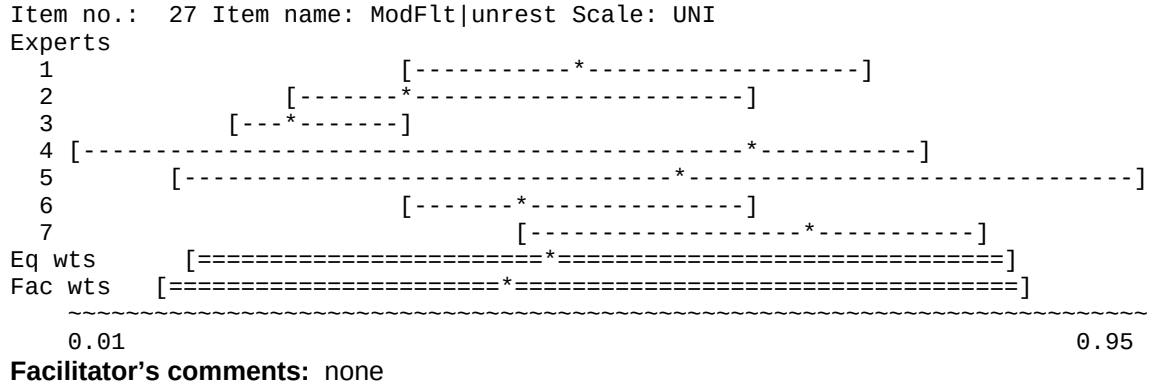
21. What is the probability of low, moderate or high rates of felt VT earthquakes, given **magma is INTRUDING**?

| | 5 %ile | 50%ile | 95%ile |
|---|---|---|---|
| Low number of felt VTs | 3.5e-6 | 0.069 | 0.34 |
| Moderate felt VTs | 0.12 | 0.43 | 0.83 |
| High felt VTs | 0.10 | 0.50 | 0.87 |

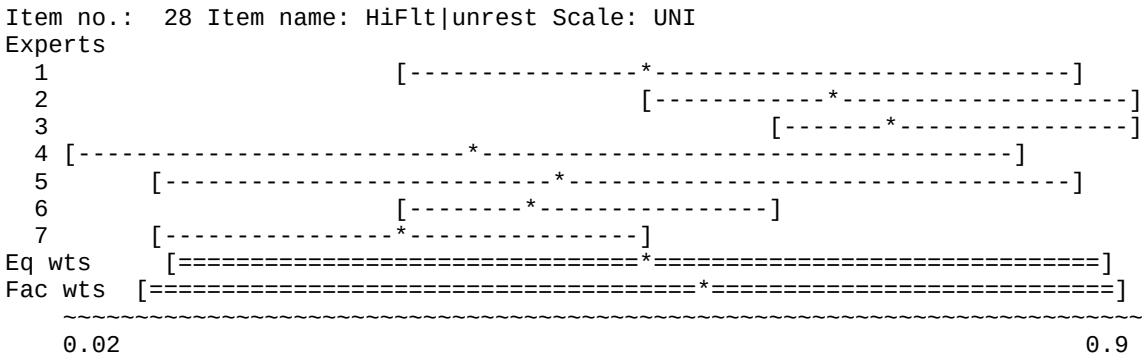
St. Vincent – 2 eruptions with no precursory seismicity?




**Facilitator's comments:** Three long-tailed Experts.




**Facilitator's comments:** none

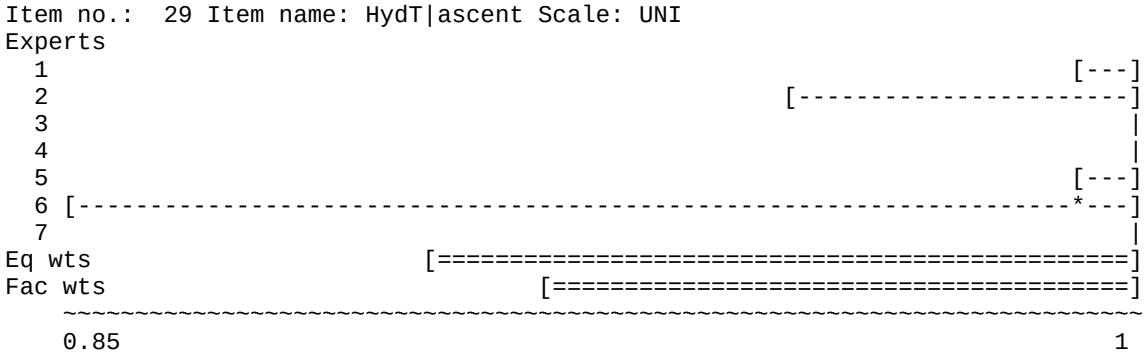



**Facilitator's comments:** none

**Perturbation of the hydrothermal system due to magma ascent**

22. What is the probability that ascending magma will perturb the hydrothermal system?

| 5 %ile | 50%ile | 95%ile |
|---|---|---|
| 0.90 | 0.9995 | 1 |

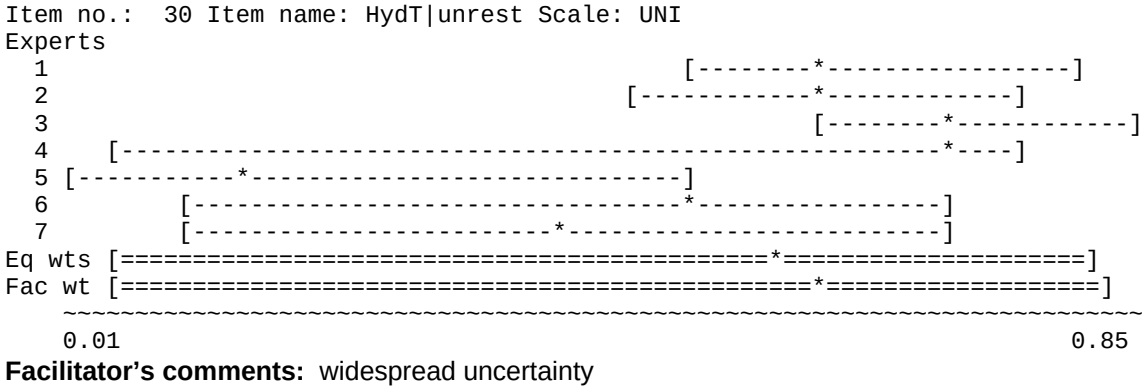



**Facilitator's comments:** only Expert 6 has (minor) qualms….Experts 3, 4 & 7 are certain!

**Perturbation of the hydrothermal system due to magmatic intrusion or unrest at depth**

23. What is the probability that there will be a perturbation of the hydrothermal system due to magmatic intrusion or unrest at depth?

| 5 %ile | 50%ile | 95%ile |
|---|---|---|
| 0.054 | 0.56 | 0.81 |

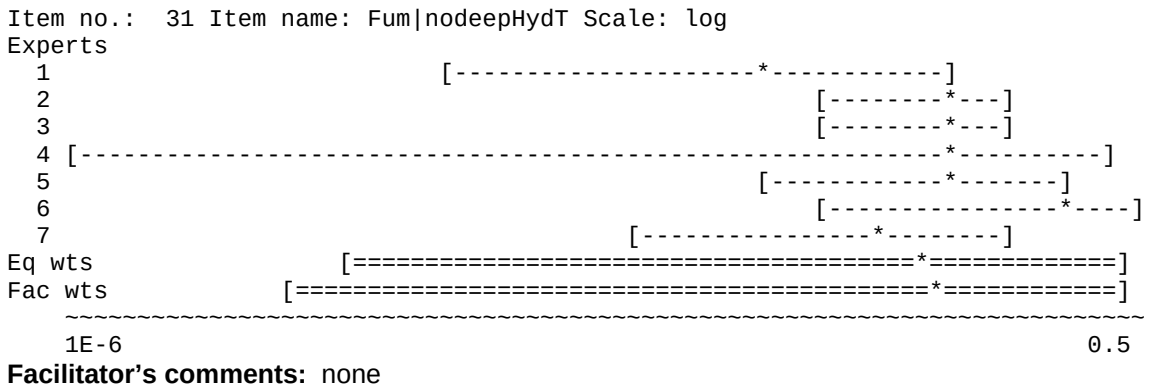



**Facilitator's comments:** widespread uncertainty

**Fumarolic activity**

24. What is the probability of observing increased high pressure, acid-rich fumarolic activity, given there is **no perturbation of the hydrothermal system** due to magmatic intrusion/unrest at depth? (NB the hydrothermal system could also be affected by non-volcanic processes – tectonic, weather/climate related etc.)
Pretty low but non-zero probability (estimate perhaps too high?)
Supercritical fluid (brine) (Campi Flegrei, Nisyros, Yellowstone (?))

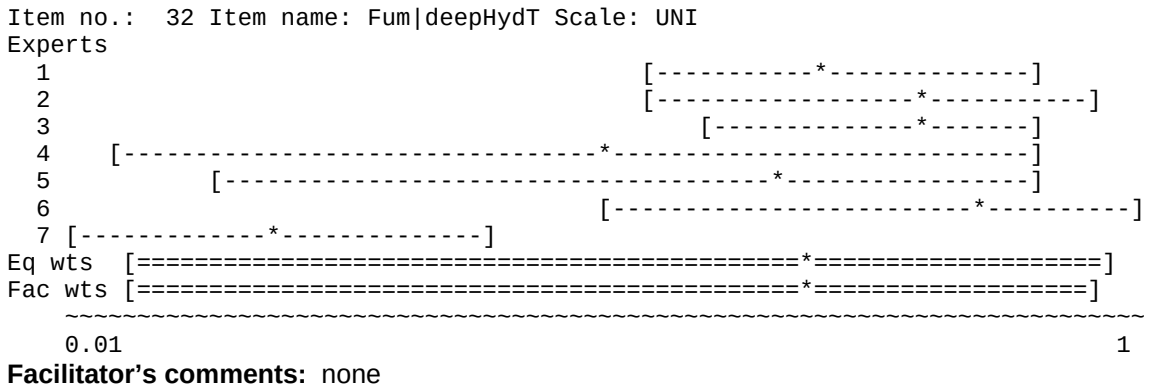
| 5 %ile | 50%ile | 95%ile |
|---|---|---|
| 3e-5 | 0.035 | 0.39 |




**Facilitator's comments:** none

25. What is the probability of observing increased high pressure, acid-rich fumarolic activity, given that there is **perturbation of the hydrothermal system** due to magmatic intrusion/unrest at depth?

| 5 %ile | 50%ile | 95%ile |
|---|---|---|
| 0.071 | 0.68 | 0.96 |



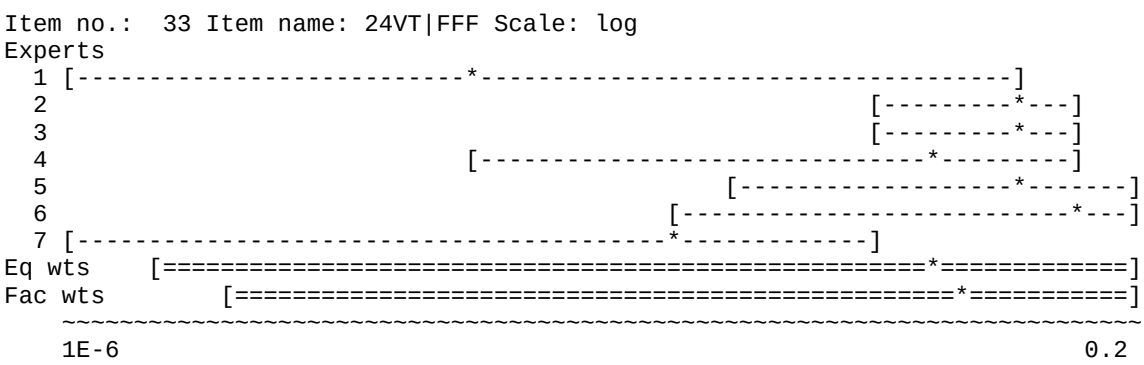

**Facilitator's comments:** none

**Shallow (<5km) seismic hypocenters**

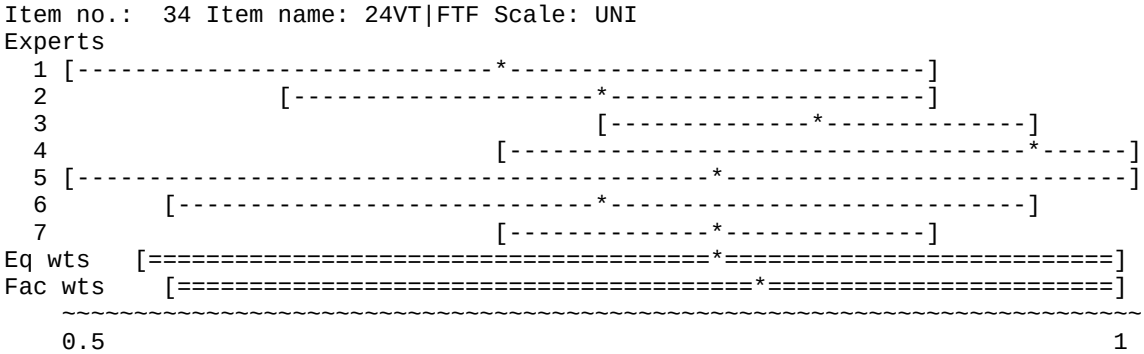
Observation of >24 VTs/month for three months

26. What is the probability of observing >24 VTs/month above 5km depth (in three month period)? (Above the magma chamber). These earthquakes could be caused magma ascent (movement of magma, rock fracturing, gas escape), or alternatively by fracturing, fluid, gas or steam movement due to hydrothermal processes.
This node has three parents: Magma ascent, Perturbation of the hydrothermal system due to magma ascent, and Perturbation of the hydrothermal system due to magmatic processes at depths >5km.
Certain combinations of states are impossible (for example, we cannot have a perturbation of the hydrothermal system due to magma ascent if magma is not ascending), which eliminates some values from the conditional probability table. Impossible states are shown in grey – these probabilities do not need to be elicited.

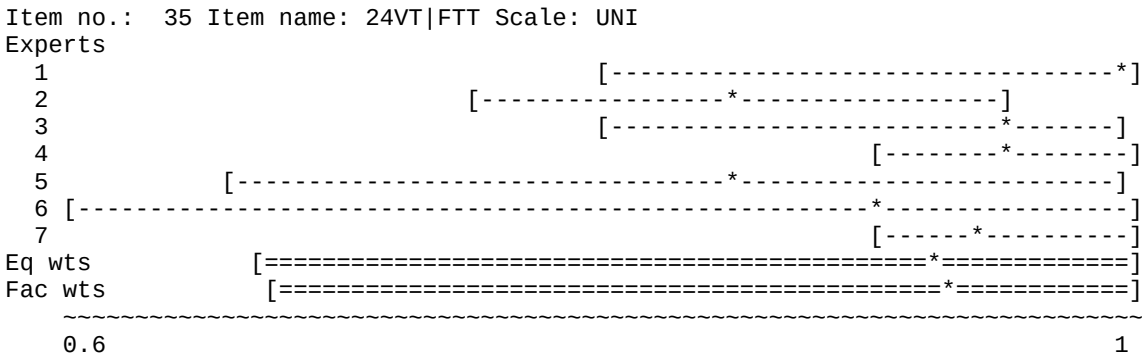
| Perturbation of hydrothermal system due to magmatic processes at depth? | Magma ascending ? | Perturbation of hydrothermal system due to magma ascent? | Seismic hypocenters 0-5 km below sea level *Probability estimate:* | | |
|---|---|---|---|---|---|
| | | | 5 %ile | 50 %ile | 95 %ile |
| FALSE | FALSE | FALSE | 3e-6 | 0.02 | 0.18 |
| FALSE | FALSE | TRUE | *Impossible* | | |
| FALSE | TRUE | FALSE | 0.54 | 0.80 | 0.99 |
| FALSE | TRUE | TRUE | 0.67 | 0.92 | 0.999 |
| TRUE | FALSE | FALSE | 0.001 | 0.46 | 0.84 |
| TRUE | FALSE | TRUE | *impossible* | | |
| TRUE | TRUE | FALSE | 0.68 | 0.88 | 0.995 |
| TRUE | TRUE | TRUE | 0.85 | 0.97 | 1 |



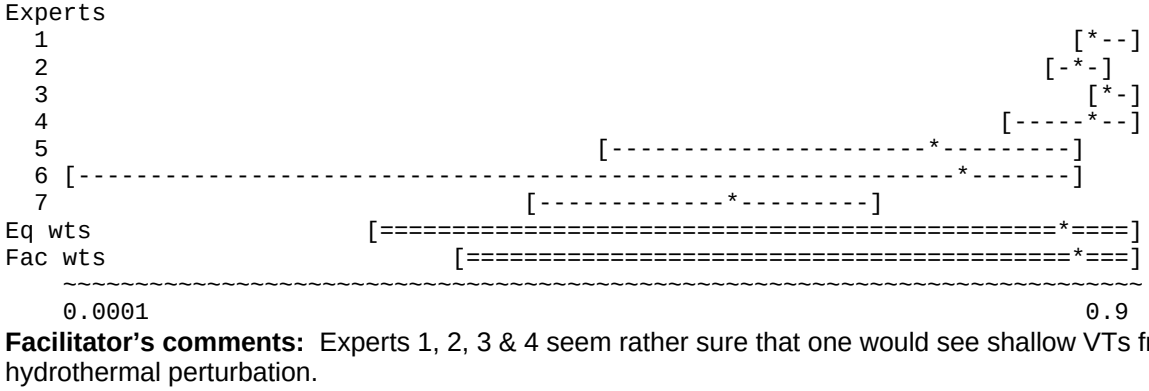

**Facilitator's comments:** none



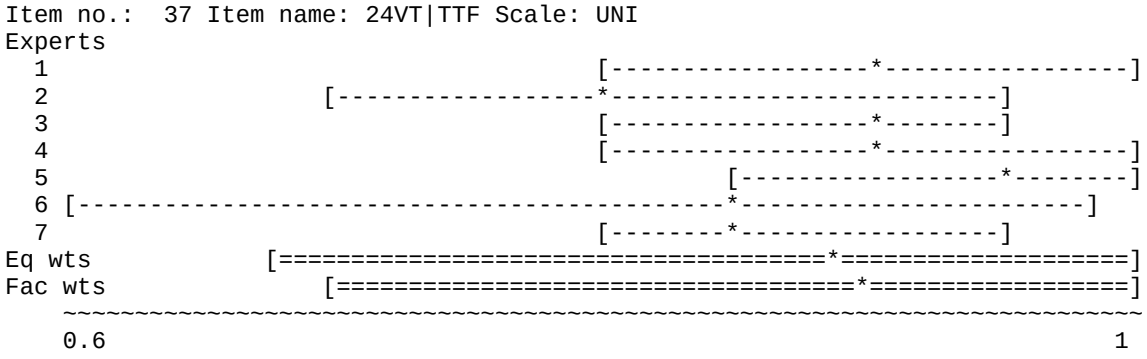

**Facilitator's comments:** none



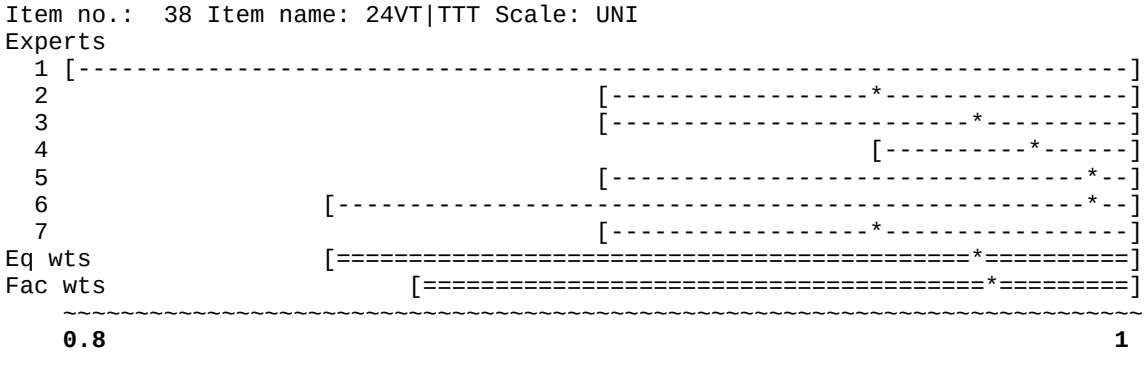

**Facilitator's comments:** none




**Facilitator's comments:** Experts 1, 2, 3 & 4 seem rather sure that one would see shallow VTs from hydrothermal perturbation.




**Facilitator's comments:** none




**Facilitator's comments:** none

**Eruption within 3 months**

27. What is the probability of an eruption occurring within three months (given what is known about the state of the hydrothermal system, and ascent of magma)?

Possible outcomes are:

0: No eruption
1: Phreatic eruption
2: Magmatic eruption

Outcomes must be mutually exclusive and exhaustive, so we need to consider the largest possible event within the three-month time frame.

This node has three parents: Magma ascent, Perturbation of the hydrothermal system due to magma ascent, and Perturbation of the hydrothermal system due to magmatic processes at depths >5km.

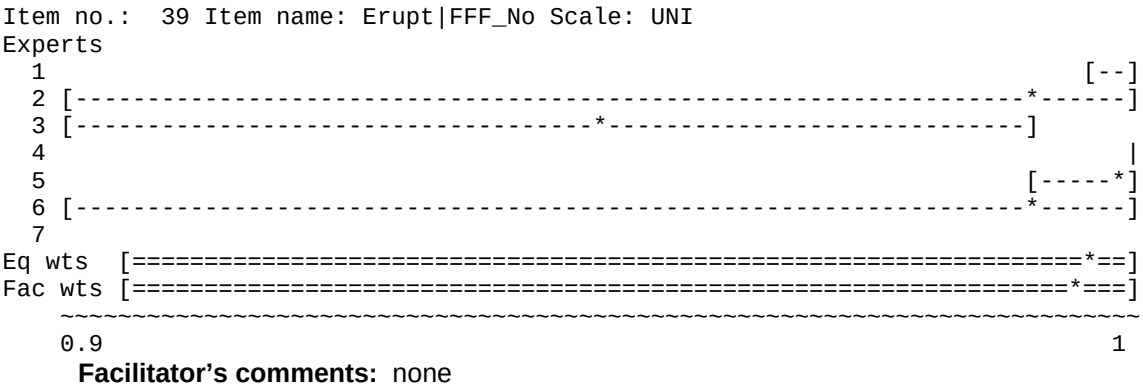
Certain combinations of states are impossible (for example, we cannot have a perturbation of the hydrothermal system due to magma ascent if magma is not ascending). This eliminates some values from the conditional probability table. Impossible states are shown in dark grey – these probabilities do not need to be elicited.

The conditional probability table to be completed (with example) is given on the following page →

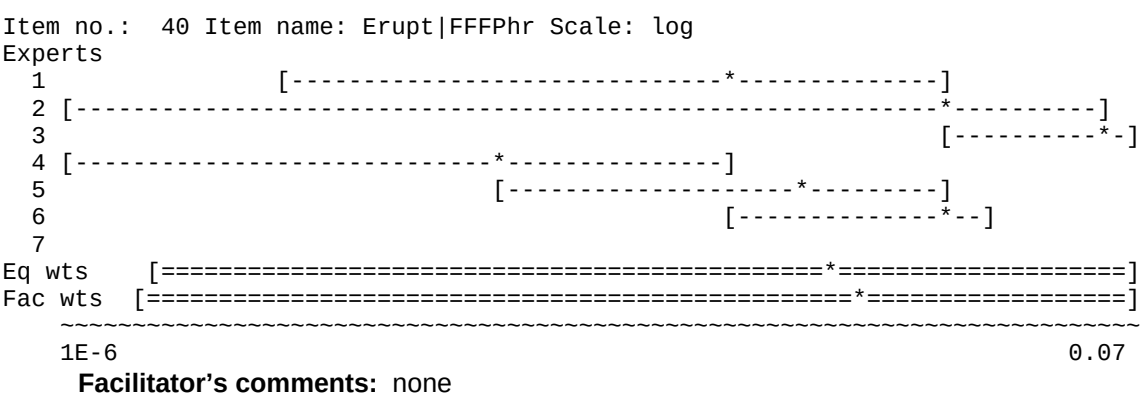
**Probability of eruption**

**50 percentile estimates across each row must sum to 1**

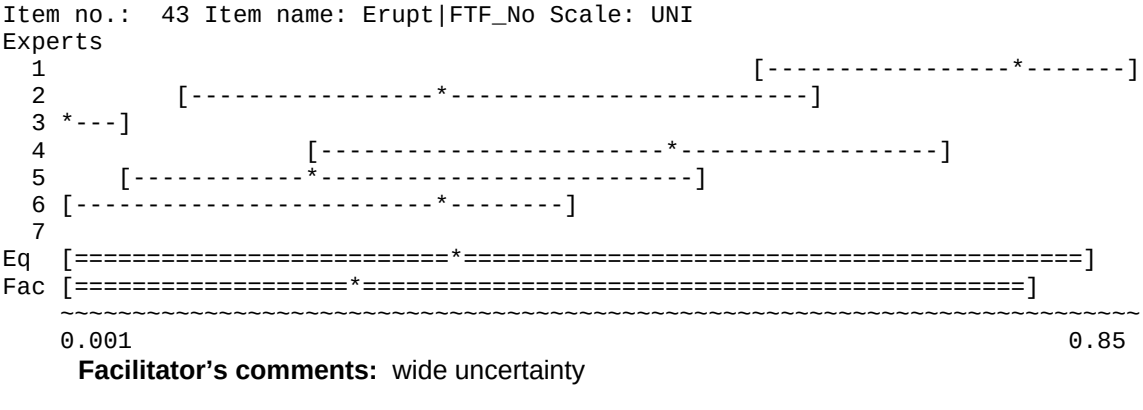
| Hydrothermal perturbation due to magmatic processes at depth? | Magma ascending? | Perturbation of hydrothermal system due to magma ascent? | **Eruption within 3 months** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | No eruption | | | Phreatic eruption only | | | Magmatic, no blast | | | Magmatic with blast | | |
| | | | 5 %ile | 50%ile | 95%ile | 5 %ile | 50%ile | 95%ile | 5 %ile | 50%ile | 95%ile | 5 %ile | 50%ile | 95%ile |
| FALSE | FALSE | FALSE | 0.91 | 0.996 | 1 | 2e-6 | 0.0028 | 0.063 | - | 0 | - | - | 0 | - |
| FALSE | FALSE | TRUE | Impossible | | | | | | | | | | | |
| FALSE | TRUE | FALSE | 0.0034 | 0.32 | 0.81 | 1e-5 | 0.058 | 0.40 | 0.057 | 0.35 | 0.72 | 0.038 | 0.29 | 0.79 |
| FALSE | TRUE | TRUE | 0.034 | 0.51 | 0.87 | 0.068 | 0.29 | 0.58 | 0.0035 | 0.13 | 0.60 | 2e-5 | 0.043 | 0.74 |
| TRUE | FALSE | FALSE | 0.62 | 0.91 | 0.998 | 0.0023 | 0.054 | 0.50 | 4e-8 | 6e-6 | 0.0096 | 1.2e-7 | 7e-6 | 0.0075 |
| TRUE | FALSE | TRUE | Impossible | | | | | | | | | | | |
| TRUE | TRUE | FALSE | 2.7e-5 | 0.39 | 0.98 | 0.013 | 0.15 | 0.48 | 0.0027 | 0.17 | 0.68 | 0.0025 | 0.14 | 0.48 |
| TRUE | TRUE | TRUE | 0.0072 | 0.14 | 0.79 | 0.052 | 0.27 | 0.60 | 0.007 | 0.27 | 0.70 | 0.006 | 0.20 | 0.79 |



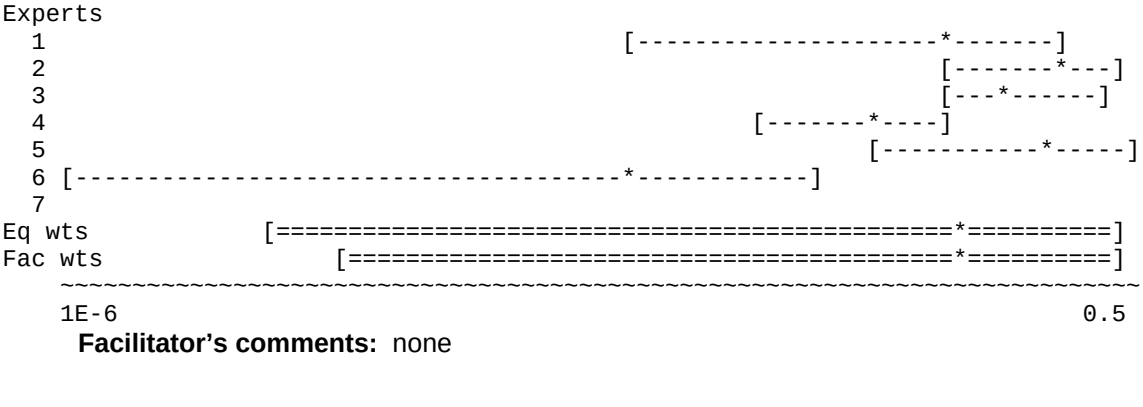

**Facilitator's comments:** none



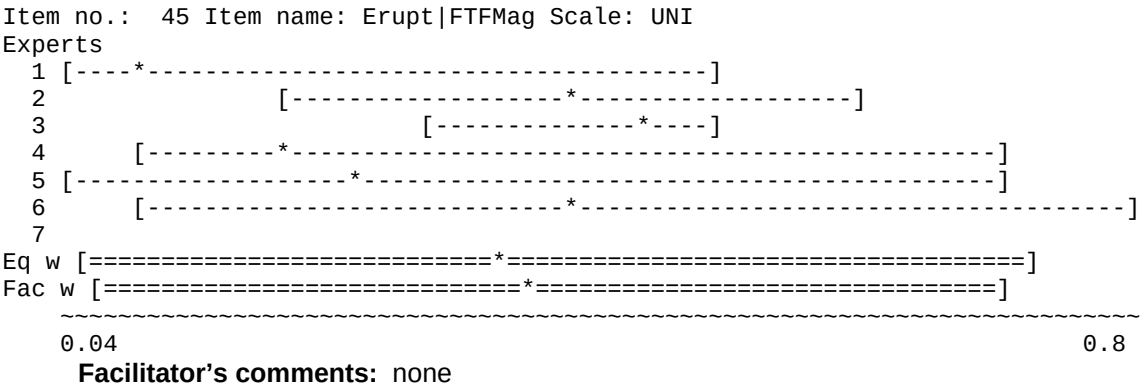

**Facilitator's comments:** none



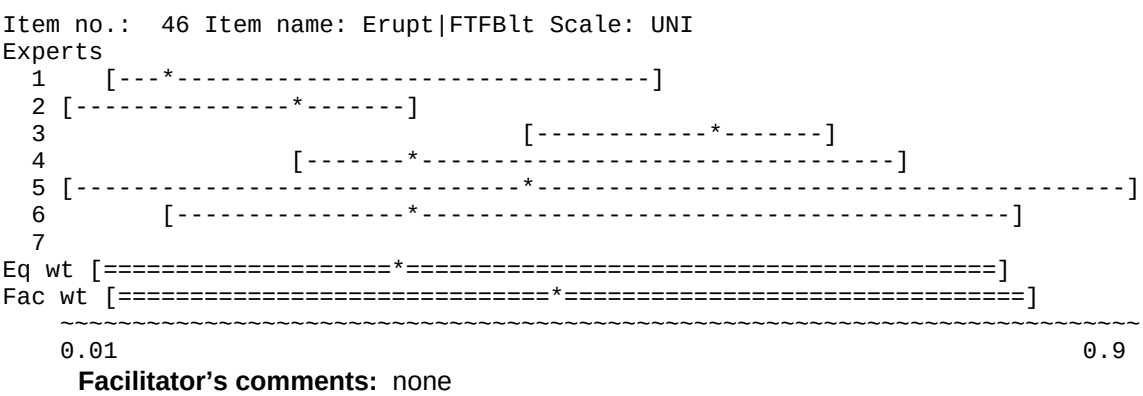

**Facilitator's comments:** wide uncertainty



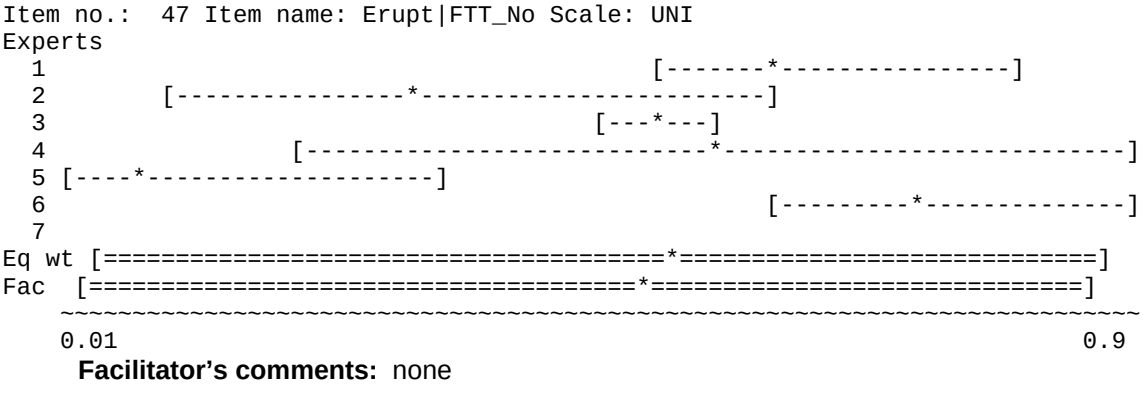

**Facilitator's comments:** none



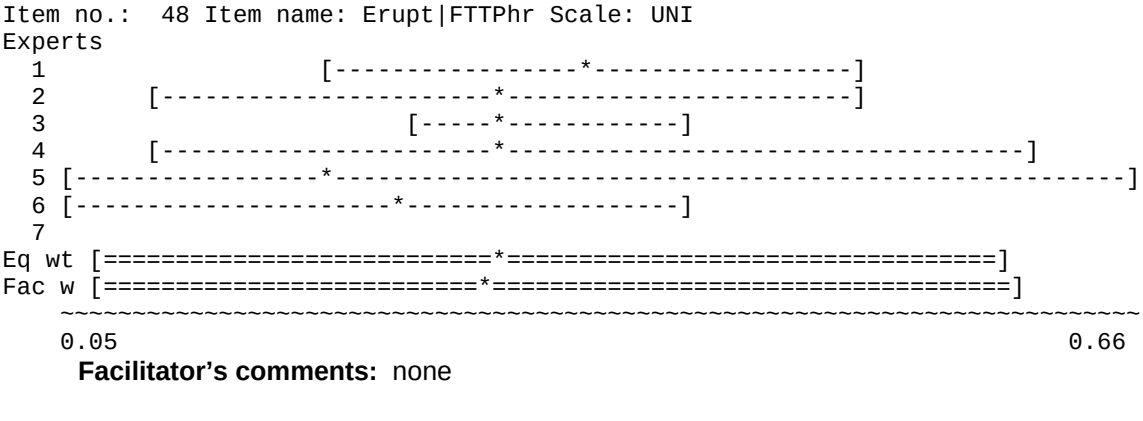

**Facilitator's comments:** none



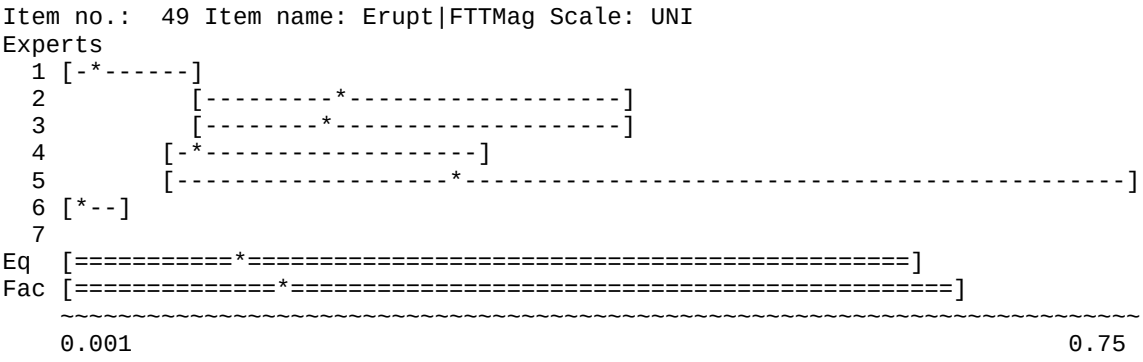

**Facilitator's comments:** none



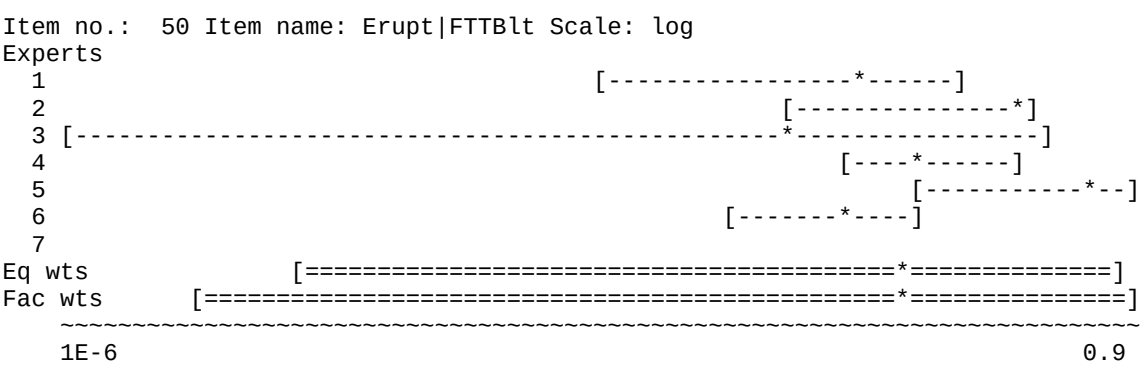

**Facilitator's comments:** none



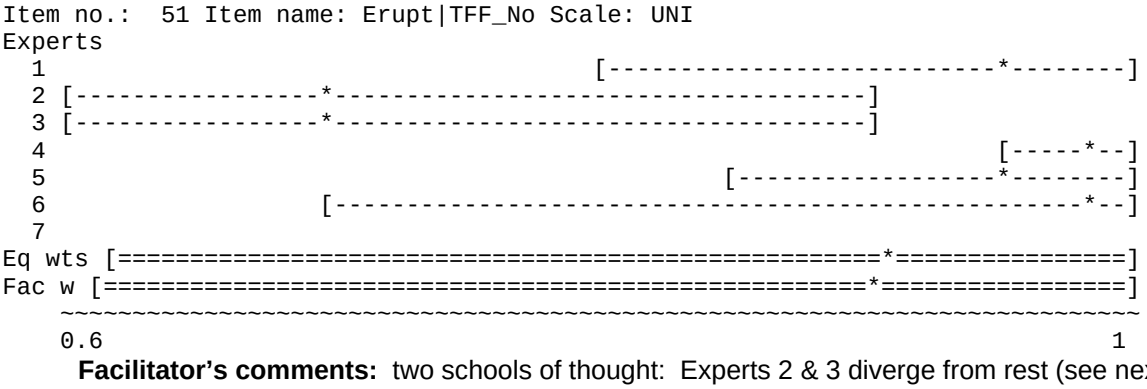

**Facilitator's comments:** none



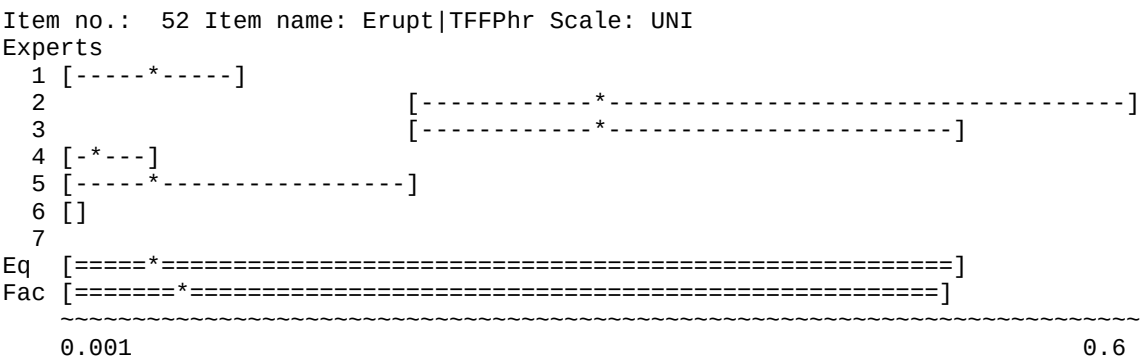

**Facilitator's comments:** wide uncertainties



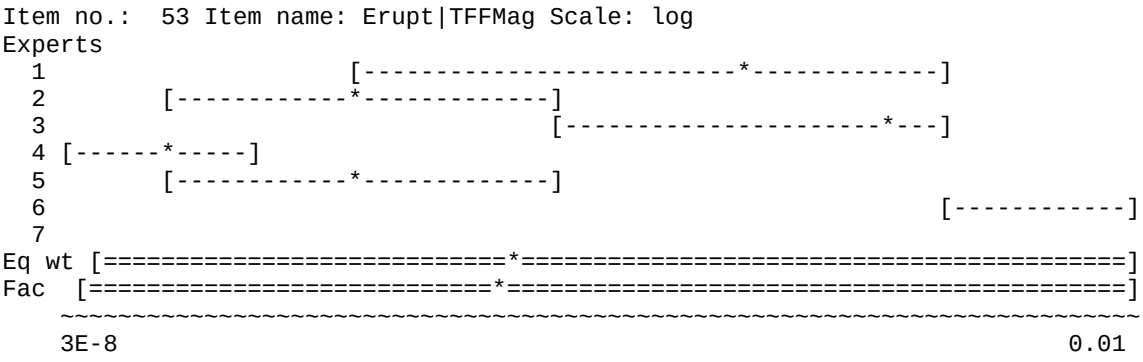

**Facilitator's comments:** Expert 3 driving lower bound right down



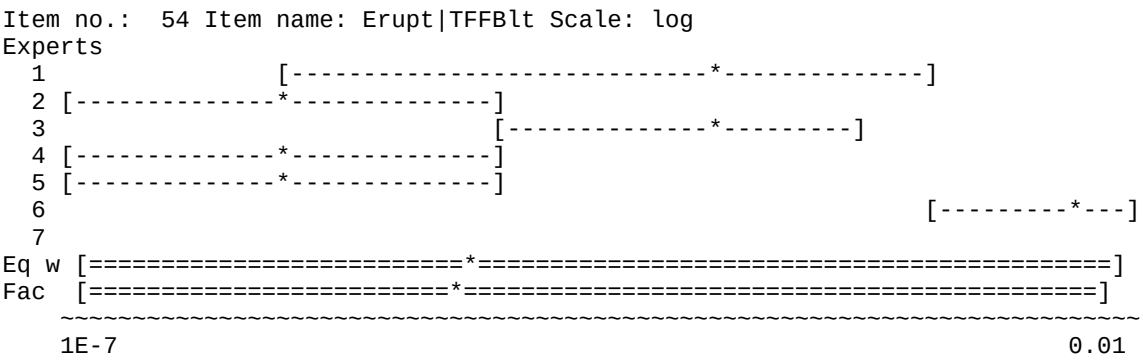

**Facilitator's comments:** two schools of thought: Experts 2 & 3 diverge from rest (see next)



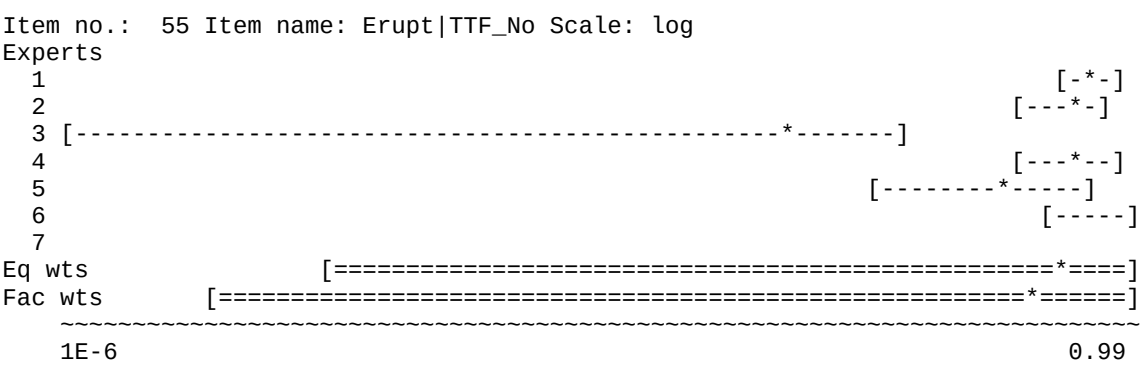

**Facilitator's comments:** Experts 2 & 3 diverge again



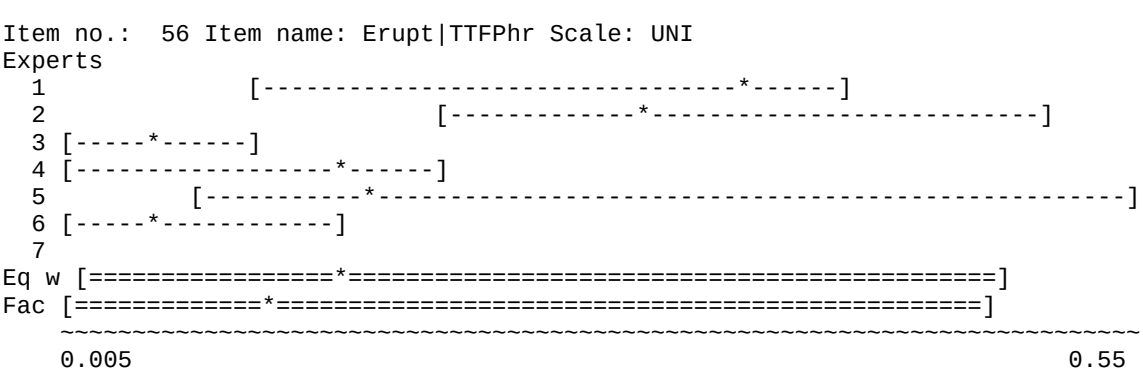

**Facilitator's comments:** none



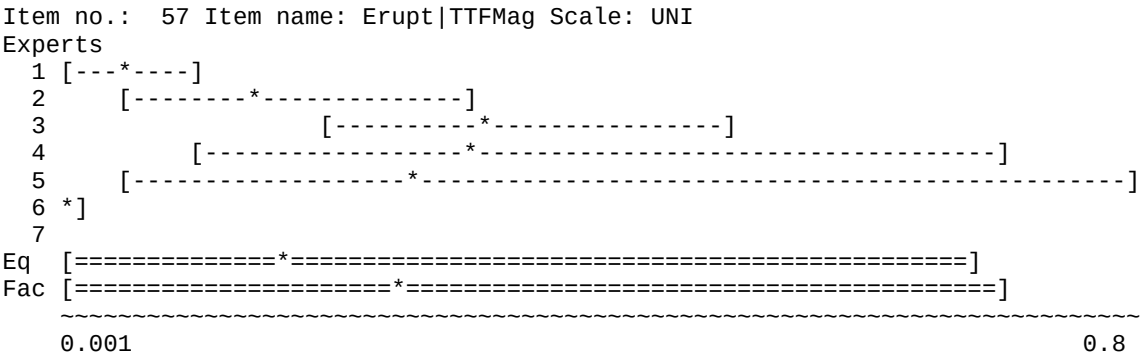

**Facilitator's comments:** Expert 6 on a limb



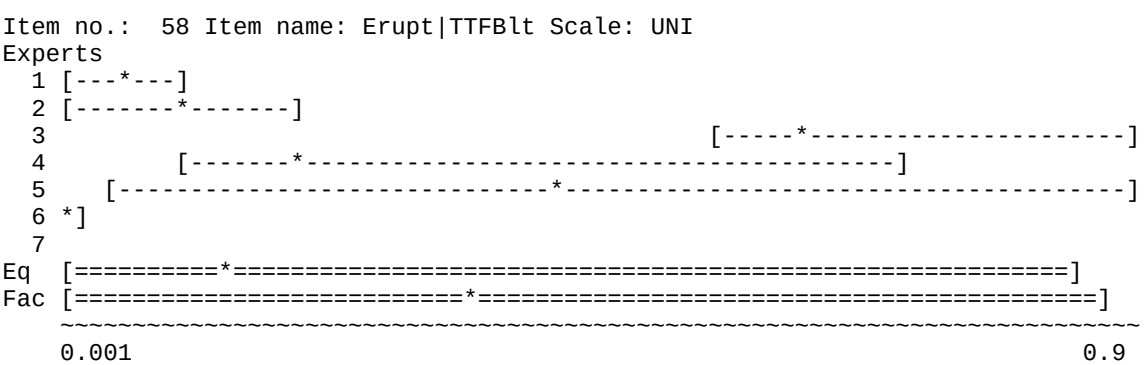

**Facilitator's comments:** Expert 3 ploughs different furrow



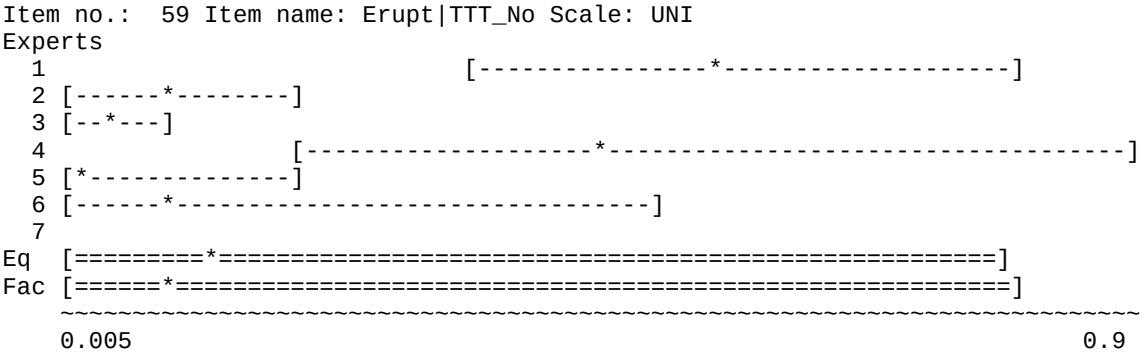

**Facilitator's comments:** none



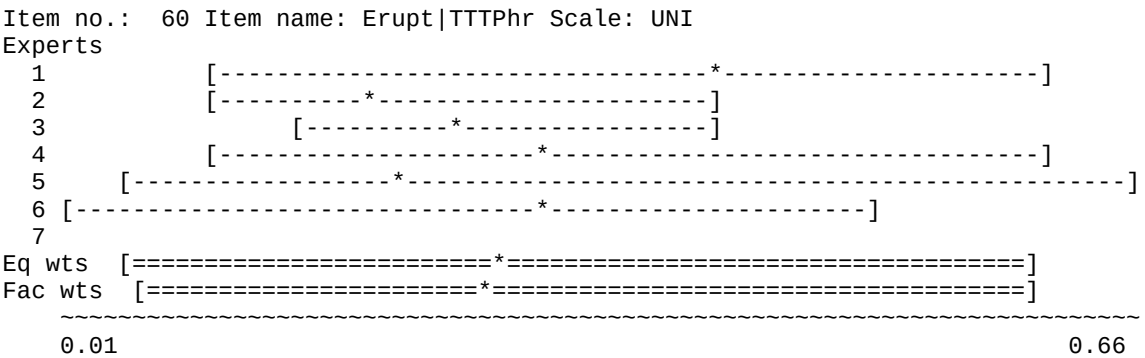

**Facilitator's comments:** none



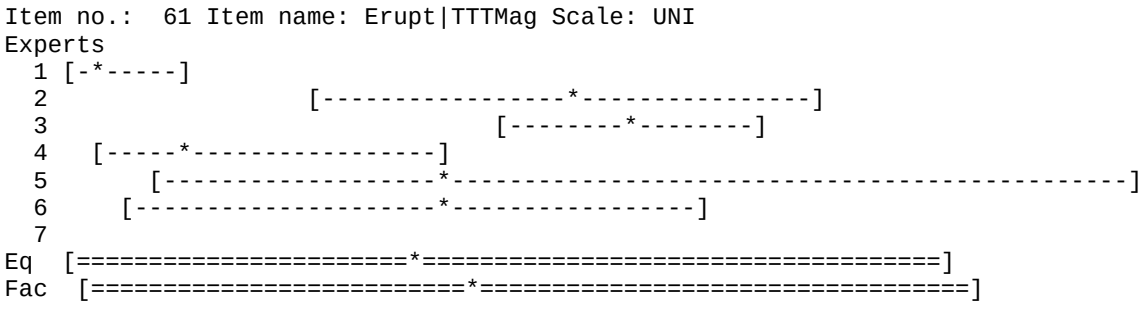

**Facilitator's comments:** none



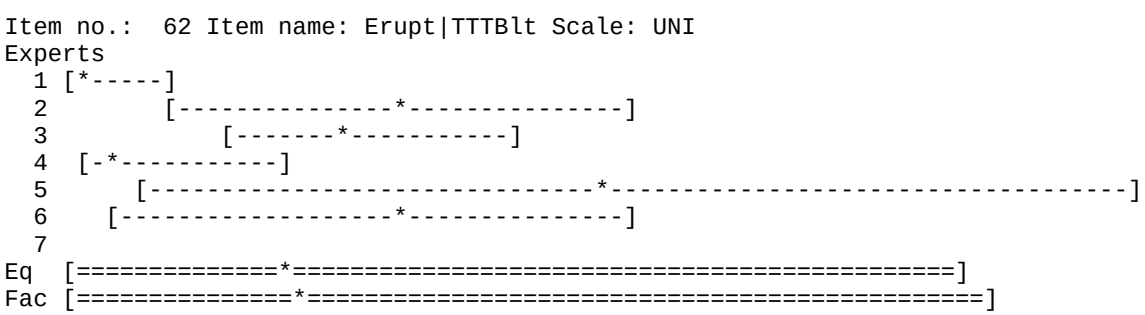

**Facilitator's comments:** two schools??




**Facilitator's comments:** good group coherence, but still wide credible intervals




**Facilitator's comments:** wide uncertainty




**Facilitator's comments:** wide uncertainty