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Hotspotting called into question *(complete version)*

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Abstract:

In may 1997, Nature published an article by Wessel and Kroenke1 presenting an ageindependent geometric technique which was supposed to "refine absolute plate motions" and "relocate extinct hotpsots". According to the authors, this technique has the potential to estimate the pseudo-age for all seamounts in a seamount chain and link cogenetic seamounts produced by hotspot ; in addition, they claim that its application points to a recent change in the Pacific Plate motion and relocates the Louisville hotspot to the Hollister ridge, south of Eltanin FZ.

Three months later, the same authors proposed to Geophysical Research Letters a note2 (published in february 1998) based on the analysis of synthetic and actual seamount data, showing that the interpretation of raw images computed by their technique is not straigthforward. This note however does not explicitely point out all the insufficiencies of the method and does not cast doubt on the conclusions resulting from its application. A careful "non-blind" examination of this technique shows that it cannot be used in practise without age information and so, it does not present any progress relative to the classical backtracking method ; in addition, the practical conclusions (such as the location of the Louisville hotpsot) are not correct3,4.

Life and death of hot-spotting

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In may 1997, *Nature* published an article by Wessel and Kroenke[1] presenting an age-independent geometric technique which was supposed to "*refine absolute plate motions*" and "*relocate extinct hotpsots*". According to the authors, this technique has the potential to estimate the pseudo-age for all seamounts in a seamount chain and link cogenetic seamounts produced by hotspot ; in addition, they claim that its application points to a recent change in the Pacific Plate motion and relocates the Louisville hotspot to the Hollister ridge, south of Eltanin FZ.

Three months later, the same authors proposed to *Geophysical Research Letters* a note[2] (published in february 1998) based on the analysis of synthetic and actual seamount data, showing that the interpretation of raw images computed by their technique is not straigthforward. This note however does not explicitely point out all the insufficiencies of the method and does not cast doubt on the conclusions resulting from its application. A careful "non-blind" examination of this technique shows that it cannot be used in practise without age information and so, it does not present any progress relative to the classical backtracking method ; in addition, the practical conclusions (such as the location of the Louisville hotpsot) are not correct[3,4].

I. Dissection of the method

Using synthetic data to explore the nature of the image of cumulative volcano amplitude (CVA), W&K[2] demonstrate that "*factors such as across-trail scatter of seamount locations, inaccurate stage poles and migration of hotspots exert strong influences on the location and appearances of CVA maxima*". Nonetheless, doing so, they consider their technique as a black box - which takes a set of seamounts as input and produces a CVA image as output - and analyze the effects that perturbations on the quality of the input may exert on the quality of the output. Here, we instead prefer look at the "inside of the black box", evaluate its practical application using real data and show that the limits of this technique could have been revealed at the beginning.

Tautology. The hot-spotting method is based[1] on "*the fact that seafloor beneath hot-spot -produced seamounts have crustal flowlines that intersect at actual hot spot locations provided there is more than one stage rotation and that hot spots are stationary*". Then, because the set stage pole used for computing flowlines is calculated in order to fit the trend of the Hawaïan-Emperor seamounts chain, the clear X on the image of cumulative volcano amplitude (CVA) which marks the location of the Hawaian hotspot is a normal consequence of geometry (Fig.1). To pretend — as W&K do — that this X"*illustrates the power of the technique*" is merely a tautology.

Interferences. In their self-criticism, W&K[2] note "*that the large, broad CVA intersections at Raratonga may in part be caused by interference by other maxima associated with large seamounts in the western Pacific*. However, they underestimate the effect of those interferences. If, instead of plotting the CVA image, we plot the crustal flowline of each volcano (Fig. 1), we observe that the bigest and brightest CVA maxima shown in their image, in the vicinity of Raratonga and Rurutu, is obtained by the intersection of flowlines issued mainly from the following different alignements : 1) the Samoa alignment, which presents an age progression from 10 to 0 Ma[5]; 2) the Marshall-Gilbert Islands (for Raratonga), which does not present any age progression[6]; and 3) the Mid-Cretaceous ridges of the Phoenix Fracture Zone[7]. However, age and/or direction constraints demonstrate that there is no possible genetic relationship between Rarotonga and any of these three alignments, and that these alignments cannot be genetically related. A similar analysis also applies to the Marquesas Islands which are located at the intersection of flowlines issued from seamouts of the Hawaian-Emperor chain, the Line Islands chain, the Central Basin Ridge and the Marquisas alignement (Fig. 1).

Consequently, in order to avoid problems of interferences and image intersections where no hotspots are present (see the CVA maxima close to the Line Islands on figure 1), one must, for all practical purposes, stop plotting flowlines at the age of volcanoes. This requirement strongly reduces the practical interest of the method! Furthermore, even so, it is not possible to avoid all the interferences : for instance, the Phoenix Islands crustal flowlines play a strong role in both Mehetia and MacDonald CVA maxima althought this alignment obviously cannot be linked with both hot-spots.

Hotspot and non-hotspot alignments. The hotspotting technique could have had some power for discriminating the hot-spot produced seamounts if - as claimed by W&K[2] - "*seamounts not created at a hotspot have flowlines that do not converge at a single point.*". However, this statement is not correct, since non-hotspot alignments may converge at a single point of maximum focus (Fig. 1). For instance, the flowlines issued from the synchronous volcanoes of Marshall-Gilbert alignment[6], the volcanoes of the Central Basin Ridge or the Phoenix FZ respectivly converge in one point of maximum focus. Any alignment created for instance within a fracture zone that is parallel to a small circle described by Hawaii-Emperor chain will experience the same fate.

Reactivation of volcanism. Some Pacific alignments - such as Line[9,10] and Cook-Austral Islands[11] - present two or more periods of volcanic activity that are separated by more than 30 Ma, and it is not possible to discriminate the resulting diagenetical volcanoes, otherwise than by measuring their age. Because the hot-spotting technique is unable to take into account the possibility of volcanic reactivation over a given alignment, these volcanoes will contribute to the same CVA, simply because they are on the same trend.

More generally, since hotspotting is a simple, geometric technique, it cannot take into account the numerous "*complexities in the tectonic development of the Mesozoic Pacific*". One can guess that if the problem of deciphering the absolute motions of plates were relevant to geometry only, it would have been already solved.

Practical application of the method

Although they recognize that the interpretation of raw CVA images is not as straightforward as initially thought, W&K[2] still keep claiming that the hot-spotting concept can be used to refine absolute plate motions *by seeking pertubations to the initial stage poles that will focus the CVA image*. One of the problems is to define the criteria that can be used practically for focusing the image. Because of the numerous complexities of Pacific volcanism, a global, statistical approach extended to all Pacific seamounts (such as the minimization of the overall standard deviation of the CVA image) has intrinsically no geological significance. Defining criteria based on statistics restricted to Hawaii and Louisville seamounts is not either an easy task, since it is not possible to modify one stage pole and keep a good fit on both alignments without modifying the other poles. In addition, volcanism along the Louisville seamount chain declined sharply after 25 Ma and was almost totally interrupted after about 11 Ma[12]. Therefore, the quality of the CVA image on Louisville only depends on volcanoes older than 11 Ma : changes in stage poles for Late Miocene and Pliocene periods will merely shift the location of the "X" of the Louisville CVA trails, but will not affect the focus of the Louisville CVA image.

Computing the absolute motions of the Pacific Plate using the conventional backtracking approach requires at least two different alignments of the same age that are as far away as possible and the checking of the resulting pole on all other synchroneous Pacific alignments. The pole of W & K[1] fits the recent bend of the Hawaian trend but fails to describe most Pacific alignments of age < 5 Ma (Fig. 2). Using the lineations of the geoid of age < 20 Ma, Wessel *et al.*[13] computed a pole that fits with the recent alignments, but does not describe the Hawaian bend. In order to reconcile the change in the Pacific plate absolute motion that probably occured in the last 5 Ma[14] with the trend of all other Pacific alignments, we propose a pole[15] that yields a bend that is less important than what is marked in the Hawaian topography, suggesting that the actual bend in the topography is likely to be related to the presence of near-by surface features[10] (such as the Molokai Fracture Zone).

Finally, the pole proposed by W&K[1] relocates the present Louisville hotspot to the Hollister Ridge, south of the Eltanin FZ, which is not consistent with the geochemical constraints[4]. The pole that we propose using conventional backtracking locates the Louisville hotspot at 50.9S, 137.6W, in the front of a volcano located near 50.5°S, 139.2°W [12] which is known to have a Louisville isotopic signature[16,17].

IV. Conclusion

W&K[2] pretend that the *hot-spotting is more objective than backtracking*. We have seen that hot-spotting is flawn by intrinsic and extrinsic errors and that its application is not age independent in practise. But in addition, it does not present any advance relative to classical backtracking. Indeed, using the few existing dated volcanoes, it is possible to "pseudo-date" most volcanoes from the Pacific by bactkracking and link the cogenetical alignments. It is true that computers are faster and allow to handle more data than paper and scissors, and that the hotspotting technique can employ all Pacific seamounts (more than 10000) that can be characterized remotely by satellite altimetry, "instead of being limited to a few hundred seamounts with dates of highly variable quality". However, the blind use of computers -"by throwing away half of the data"[18,19] - fails to take into account the complexity of nature and leads to erroneous conclusions. Rapidity is not necessarily synonym of good science and one should better remind the words of Claudio Monteverdi, whose music, written back in the 16th century, is still alive : "I know that it is possible to compose fast but fast and well do not go together well".

Acknowledgements
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Figure 1A : Dissection of the Hot-spotting technique.

Crustal flowlines are drawn for a selection of alignments. We chose those volcanoes in order to explain some of the brightest CVA maxima observed on Fig. 6 of W&K[1] (dotted thick lines; A-G) and keep the lisibility of the picture. Note that: the "Raratonga CVA maximum" (A) is mainly the result of the intersection of the Marshall-Gilberts Islands and Samoa crustal flowlines ; "Mehetia CVA maximum" (B) and "Macdonald CVA maximum" (C) are underlined both by the flowlines from the Phoenix Islands; "Fatuhiva CVA maximum" (D) occurs at the intersection of flowlines from Northern Line Islands, Central Basin Ridge and Marquesas alignment; the Emperor Chain flowlines produce two CVA maximum artefacs (E and F), with respectivly the Northern Line Islands and the Central Basin Ridge flowlines. Oceanic plateaux (in orange) and Volcanoes (in red) were digitilised from the gravity map of Sandwell & Smith[8].

Figure 1B

Small circles computed with W&K's most recent pole[1] (25°N, 27°W). This pole fails to describe most of the alignments of age< 5Ma (underlined in yellow).

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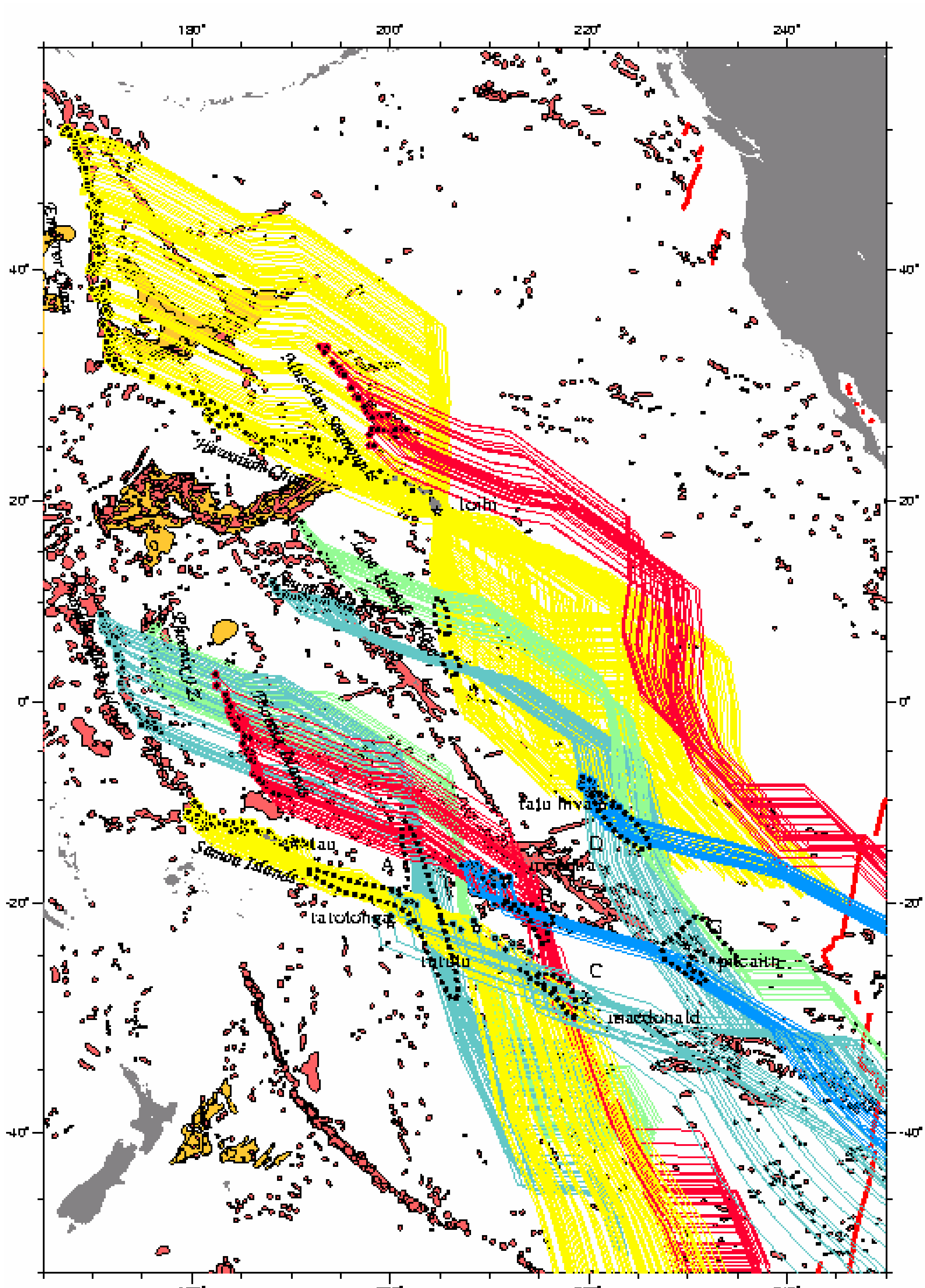

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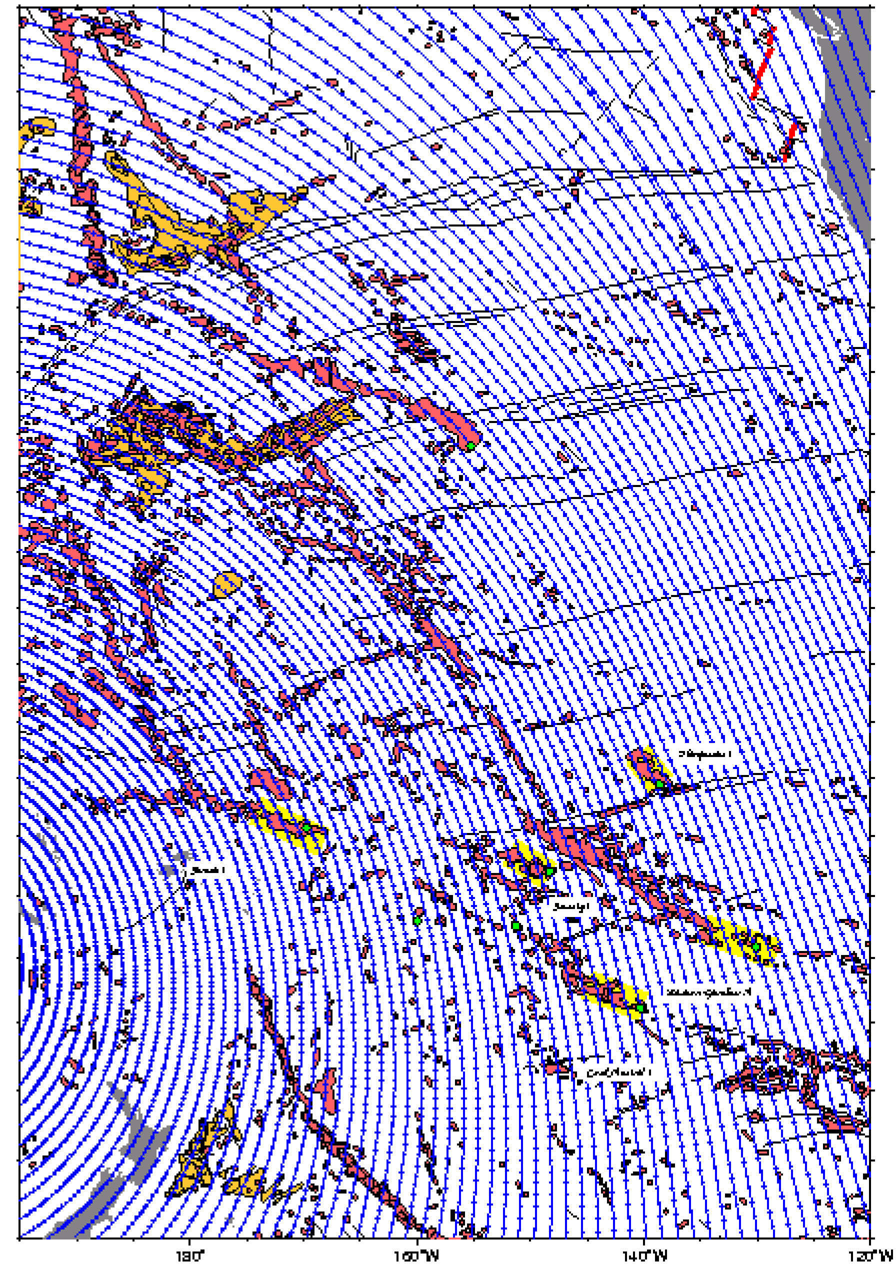

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Small circles computed with W&K's most recent pole1 (25°N, 27°W). This pole fails to describe most of the alignments of age< 5Ma (underlined in yellow).