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RESEARCH ARTICLE

THE STREAM-LENGTH GRADIENT INDEX AND THE CORRESPONDING LANDFORM STRUCTURES OVER THE KIULU RIVER, NORTHWEST SABAH

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ABSTRACT

In this paper, we explored the relationship between the stream-length gradient index over the Kiulu River upstream and its respective landform. The knickpoints derived from stream-length gradient index detected sudden drop in elevation that may be associated with recent tectonic activity over NW Sabah. To illustrate the changes in the stream profile, two knickpoints, F1 which coincided with historical earthquakes, and F2 which showed peak anomaly are selected. The landform over knickpoint F1 showed river diversions whereas the landform over knickpoint F2 showed deep ponding. Both field sites, however showed consistent alternation between rapids and ponding forming a step-like landform where the inferred normal fault is oriented at N40E. The stretched landform over the Kiulu river sites supports an extension setting that may be associated with gravity-sliding tectonics over NW Sabah.

KEYWORDS

stream-length gradient index, knickpoints, extension tectonics.

1. INTRODUCTION

Drainage networks have the potential to record the effects of surface processes influenced by tectonic uplift, lithology, climate and erosion. Recent tectonic uplift over a landform may be elucidated by computing the stream-length gradient index over the stream network to highlight points of anomalous gradient or elevation drop (Chen et al., 2003; Hayakawa and Oguchi, 2006; Troiani and Della Seta, 2008; Hayakawa and Oguchi, 2009; Font et al., 2010; Pérez-Peña et al., 2010; Troiani et al., 2014; Mathew et al., 2016; Menier et al., 2017; Siddiqui et al., 2017). The stream-length gradient index thus has great potential to be applied to tectonically active regions like Sabah.

In Northwest Sabah both compressional and an extensional tectonics occur (Hesse et al., 2010; Hall, 2013; Sapin et al., 2013; Tongkul, 2016, 2017; Wang et al., 2017). It would be of interest to know how these compressional and extensional tectonics affects surface process along several major drainage system in Northwest Sabah. During the last two years, morphometric studies, including stream-length index, have been computed on several major drainage system surrounding Mount Kinabalu, one of which is the Kiulu River Drainage basin. This paper presents part of the finding of this study.

1.1 Study Area

The study area focuses on the Tuaran drainage system which is located at the western flank of the Kinabalu granite (Figure 1). The area is underlain by Oligocene sedimentary rocks of the Crocker Formation comprising of deformed sandstone and mudstone of marine origin that were uplifted during the Early Miocene. The fold-thrusted sandstone formed as a part of the greater Crocker accretionary Prism (Hazebroek and Tan, 1993; Hutchison, 1996; Hall et al., 2008; Lambiase et al., 2008). The stream of interest within the Tuaran water catchment coincides with the Kiulu River illustrated as dotted lines in Figure 1.

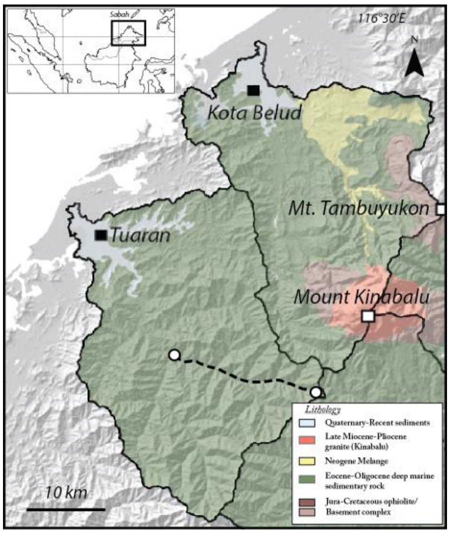

Figure 1: The location of the stream of interest coinciding with the Kiulu river. The lithology bedrock is homogenously of a heavily deformed sandstone-mudstone bedrock. The studied stream of interest is highlighted by the dotted line interval.

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2. Data and Methodology

The data applied in this study is mainly 30-m SRTM DEM. The stream is segmented at an interval of approximately 100-m each with Topotoolbox 2 (Schwanghart and Scherler, 2014). In this paper, we compute the established stream-length gradient index (Hack, 1957; Hack, 1973). The equation can be illustrated in the form of:

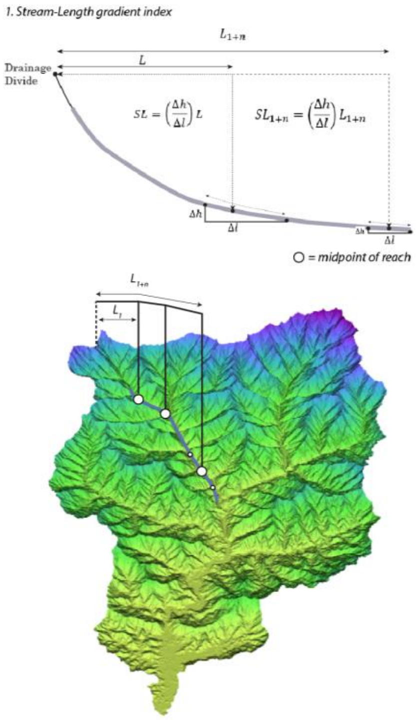

Figure 2: The stream-length gradient index computation concept from a cross-section and 3-dimensional perspective. The length is derived from the basin divide distance to each point of the reach.

3. Results and Discussion

The stream-length gradient index has been computed over the sub-catchments of the greater Tuaran basin (Figure 3). The high anomaly of the stream-length gradient index is plotted in yellow while the peaks as red. At least six significant knickpoints occur along the upstream of Kiulu River. Each knickpoints shows sudden change in river profiles. To illustrate this landform changes, two knickpoints, F1 and F2 are selected, whereby knickpoint F1 coincides with an earthquake of magnitude 3.5, whereas knickpoint F2 is of an anomaly peak.

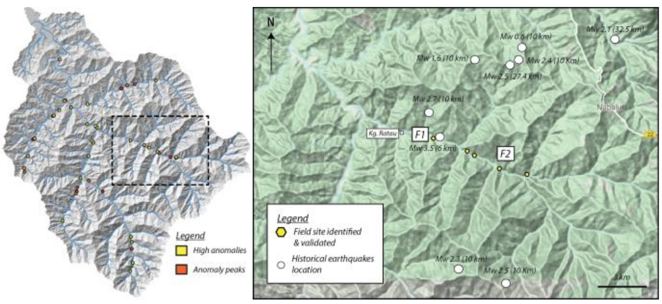

Figure 3: The stream-length gradient index at 100-m interval computed over the 30-m resolution DEM. The knickpoints of interest were plotted over the Google Terrain map. Two main sites of interest were illustrated namely field site 1 & 2 (FS 1 & 2). The historical quake data is provided by the National Disaster Research Centre (NDRC) Universiti Malaysia Sabah.

The landform over knickpoint F1 shows heavily sinuous stream with multiple alternating ponding and rapid intervals. In contrast, the knickpoint over field site 2 (F2) shows deep ponding right after the knickpoint (Figure 4). However, both field sites shared the common characteristic of an alternating ponding and rapids interval that is contiguous throughout the stream. The major fault trend of uplift is suggested to orient at N40E at both field sites.

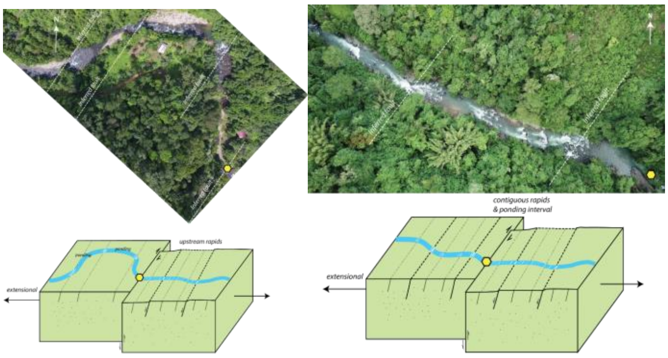

Figure 4: The landform at the field site 1 suggested highly sinuous stream that may be actively shifted through ongoing landform motions. In contrast, field site 2 shows a significantly deep ponding right after the postulated knickpoint location suggesting a significant downthrown block feature.

In general, both landforms suggested river diversion as a consequence of a minor strike-slip motion that had occurred in tandem with the uplift. Based on the landform morphology and characteristics, the tectonics inferred over the Kiulu river is of an extensional regime (Figure 5).

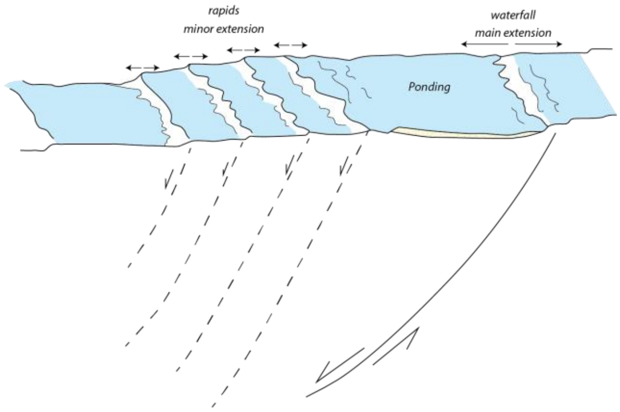

Figure 5: The main extension over Kiulu river is suggested by the waterfall feature while the consequent minor extension is highlighted by the rapids. The extension is suggested by the landform stretching morphology over the Crocker Formation sandstone and mudstone sequence. At a site with a greater uplift, the tectonic consequence extent can be discerned through the presence of deep ponding. Deep ponding correlates to a significant downthrown block portion. In contrast, sites with relatively lower uplift, is suggested by shallower ponding-rapids interval that forms part of the contiguous extension. The step-like landform along the river is interpreted to be due to the presence of numerous minor normal faults trending N40E.

4. Conclusion

This study has shown that Kiulu River shows extension tectonics based on the landform morphology, where alternating intervals of ponding and rapids occur over the knickpoints. The extension is facilitated by normal faults trending N40E. This extension may be associated with gravity sliding in Northwest Sabah.

References

Chen, Y.C., Sung, Q., Cheng, K.Y., 2003. Along-strike variations of morphotectonic features in the Western Foothills of Taiwan: tectonic implications based on stream-gradient and hypsometric analysis. Geomorphology, 56(1-2), 109-137.

Font, M., Amorese, D., Lagarde, J.L., 2010. DEM and GIS analysis of the stream gradient index to evaluate effects of tectonics: The Normandy intraplate area (NW France). Geomorphology, 119(3), 172-180. doi: https://doi.org/10.1016/j.geomorph.2010.03.017

Hack, J.T., 1957. Studies of longitudinal stream profiles in Virginia and Maryland (Vol. 294): US Government Printing Office.

Hack, J.T. 1973. Stream-profile analysis and stream-gradient index. Journal of Research of the US Geological Survey, 1(4), 421-429.

Hall, R., 2013. Contraction and extension in northern Borneo driven by subduction rollback. Journal of Asian Earth Sciences, 76, 399-411. doi: https://doi.org/10.1016/j.jseaes.2013.04.010

Hall, R., van Hattum, M.W.A., Spakman, W., 2008. Impact of India–Asia collision on SE Asia: The record in Borneo. Tectonophysics, 451(1), 366-389. doi: https://doi.org/10.1016/j.tecto.2007.11.058

Hayakawa, Y.S., Oguchi, T., 2006. DEM-based identification of fluvial knickzones and its application to Japanese mountain rivers. Geomorphology, 78(1-2), 90-106.

Hayakawa, Y.S., Oguchi, T., 2009. GIS analysis of fluvial knickzone distribution in Japanese mountain watersheds. Geomorphology, 111(1-2), 27-37.

Hazebroek, H., Tan, D., 1993. Tertiary tectonic evolution of the NW Sabah continental margin. Bulletin of the Geological Society of Malaysia, 33, 195-210.

Hesse, S., Back, S., Franke, D., 2010. The structural evolution of folds in a deepwater fold and thrust belt–a case study from the Sabah continental margin offshore NW Borneo, SE Asia. Marine and Petroleum Geology, 27 (2), 442-454.

Hutchison, C.S., 1996. The 'Rajang accretionary prism' and 'Lupar Line' problem of Borneo. Geological Society, London, Special Publications, 106(1), 247-261. doi:10.1144/gsl.sp.1996.106.01.16

Lambiase, J.J., Tzong, T.Y., William, A.G., Bidgood, M.D., Brenac, P., Cullen, A.B., 2008. The West Crocker formation of northwest Borneo: A Paleogene accretionary prism. Special Papers-Geological Society of America, 436, 171.

Mathew, M.J., Menier, D., Siddiqui, N., Ramkumar, M., Santosh, M., Kumar, S., Hassaan, M., 2016. Drainage basin and topographic analysis of a tropical landscape: Insights into surface and tectonic processes in northern Borneo. Journal of Asian Earth Sciences, 124, 14-27.

Menier, D., Mathew, M., Pubellier, M., Sapin, F., Delcaillau, B., Siddiqui, N., Santosh, M., 2017. Landscape response to progressive tectonic and climatic forcing in NW Borneo: Implications for geological and geomorphic controls on flood hazard. Scientific reports, 7(1), 457.

Pérez-Peña, J.V., Azor, A., Azañón, J.M., Keller, E.A., 2010. Active tectonics in the Sierra Nevada (Betic Cordillera, SE Spain): Insights from geomorphic indexes and drainage pattern analysis. Geomorphology, 119(1-2), 74-87.

Sapin, F., Hermawan, I., Pubellier, M., Vigny, C., Ringenbach, J.C., 2013. The recent convergence on the NW Borneo Wedge—a crustal-scale gravity gliding evidenced from GPS. Geophysical Journal International, 193(2), 549-556.

Schwanghart, W., Scherler, D., 2014. TopoToolbox 2–MATLAB-based software for topographic analysis and modeling in Earth surface sciences. Earth Surface Dynamics, 2(1), 1-7.

Siddiqui, S., Castaldini, D., Soldati, M., 2017. DEM-based drainage network analysis using steepness and Hack SL indices to identify areas of differential uplift in Emilia–Romagna Apennines, northern Italy. Arabian Journal of Geosciences, 10(1), 3.

Simons, W., Socquet, A., Vigny, C., Ambrosius, B., Haji Abu, S., Promthong, C., Morgan, P., 2007. A decade of GPS in Southeast Asia: Resolving Sundaland motion and boundaries. Journal of Geophysical Research: Solid Earth, 112(B6).

Socquet, A., Simons, W., Vigny, C., McCaffrey, R., Subarya, C., Sarsito, D., Spakman, W., 2006. Microblock rotations and fault coupling in SE Asia triple junction (Sulawesi, Indonesia) from GPS and earthquake slip vector data. Journal of Geophysical Research: Solid Earth, 111(B8).

Tongkul, F., 1990. Structural style and tectonics of Western and Northern Sabah. Geol. Soc. Malaysia, Bull. 27, 227 - 239.

Tongkul, F., 1991. Tectonic evolution of Sabah, Malaysia. Journal of Southeast Asian Earth Sciences, 6(3-4), 395-405.

Tongkul, F., 1993. Tectonic control on the development of the Neogene basins in Sabah, East Malaysia. Geol. Soc. Malaysia, Bulletin, 33, 95-103.

Tongkul, F., 1994. The Paleogene basins of Sabah, East Malaysia. AAPG International Conference and Exibition '94.

Tongkul, F., 2016. The 2015 Ranau Earthquake: Cause and Impact, 32.

Tongkul, F., 2017. Active Tectonics in Sabah—Seismicity and Active Faults. Bulletin of the Geological Society of Malaysia, 64, 27 - 36.

Troiani, F., Della Seta, M., 2008. The use of the Stream Length–Gradient index in morphotectonic analysis of small catchments: A case study from Central Italy. Geomorphology, 102(1), 159-168.

Troiani, F., Galve, J.P., Piacentini, D., Della Seta, M., Guerrero, J., 2014. Spatial analysis of stream length-gradient (SL) index for detecting hillslope processes: A case of the Gállego River headwaters (Central Pyrenees, Spain). Geomorphology, 214, 183-197. doi: https://doi.org/10.1016/j.geomorph.2014.02.004

Wang, Y., Wei, S., Wang, X., Lindsey, E.O., Tongkul, F., Tapponnier, P., Sieh, K., 2017. The 2015 M w 6.0 Mt. Kinabalu earthquake: an infrequent fault rupture within the Crocker fault system of East Malaysia. Geoscience Letters, 4(1), 6.