Hydraulic fracture b-value from microseismic events in different regions

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Summary

The recorded magnitude of the microseismic events is predominantly a result of the hydraulic fracturing process. The term b-value is simply a linear relationship that results when the logarithm of the frequency of events is plotted versus their magnitude. A larger b-value implies that more small magnitude events occur and fewer large ones, which results in a steeper slope. A small b-value implies that more large magnitude events occur and fewer small ones, which cause a lower b-value.

A comparative analysis is performed on b-values derived from microseismic data recorded in different unconventional oil and gas resource plays. This analysis is based on the *Gutenberg-Richter relation*. The analysis of the datasets used in this study show that the computed b-value from microseismic varied across different regions. The Initial findings show that b-values for the Bakken, Barnett, Eagleford, Marcellus, Montney and Muskwa formations are 2.32, 2.45, 1.09, 2.01 and 1.05 respectively. These values deviate from the typical b-value of about 1 found in earthquake seismology. While the b-value parameter is influenced by some reservoir elastic properties, in-situ stress conditions and fluid treating parameters, this deviation can also be primarily a consequence of catalogue incompleteness.

Introduction

Microseismic events occur as a result of stress and pressure changes caused by hydraulic fractures (Warpinski et al., 2004). These events are small movements of a limited area of rock which produces a magnitude. In the 1940's, Gutenberg and Richter identified a relationship between the frequency of earthquakes and their magnitudes. The *Gutenberg-Richter relation* is being applied to microseismic datasets which can often contain thousands of events. Though many elements can impact the number of events that are recorded, such as noise and viewing distance, microseismic events occur frequently and in a short period of time. Stein and Wysession (2003) discussed that when using the *Gutenberg-Richter relation*, that b is approximately equal to 1 over "long time scales and large spatial scales". The authors also mentioned that on smaller scales sometimes the b-value can vary significantly and can approach 2.5. The nature of this data provides a good statistical basis to perform b-value analysis on, especially across many different regions where hydraulic fracturing is conducted.

Method/Results

Gutenberg and Richter (1954) determined that the *frequency-magnitude relation* follows a power-law and is given by:

$$\log_{10} N = a - bM, \quad (1)$$

where M is the magnitude, N is the number of events within a particular magnitude bin M (here given in 0.2 magnitude units) and a and b are constants derived from empirical data. The magnitudes of the microseismic events were supplied from the six different regions. Microseismic magnitudes are based on the shear wave amplitudes because they are typically the largest.

As an example, Figure 1 shows the best fit line through the steepest part of the frequency-magnitude curve of the Montney formation. Here, the error in magnitude is assumed to be negligible. Similarly, as shown in table 1, the b-values were computed for each of the other formations: Bakken, Barnett, Eagleford, Marcellus and Muskwa.

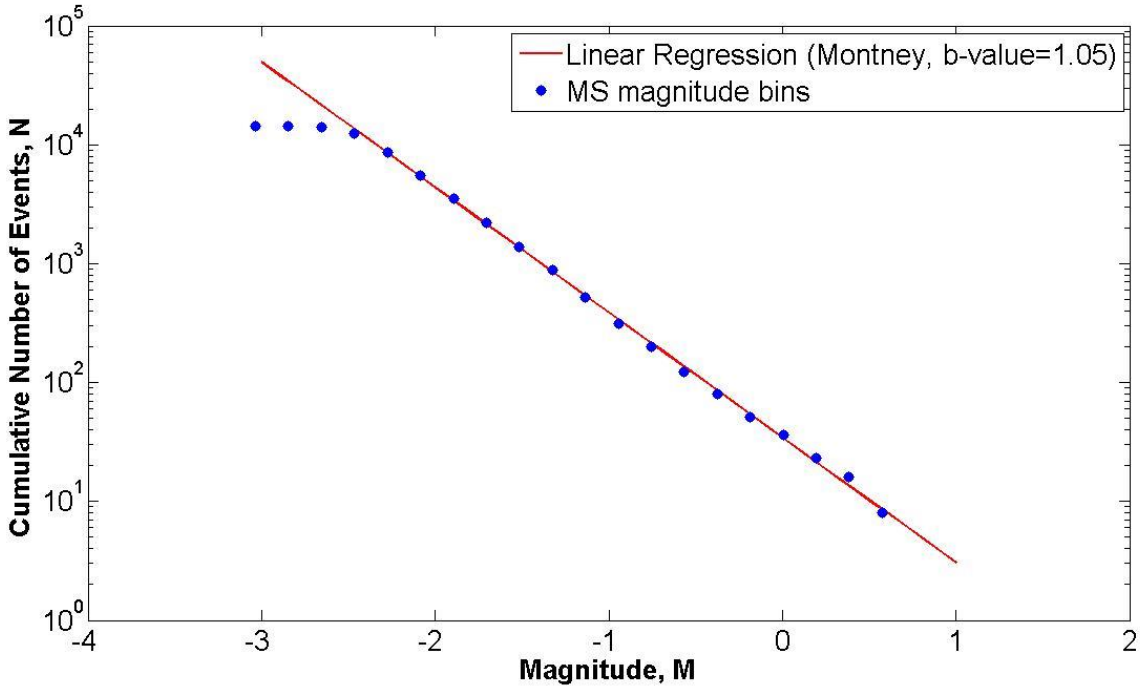

Figure 1: Example frequency-magnitude plot showing cumulative curve versus magnitude and a b-value of 1.05.

The b-values for the microseismic datasets were slightly higher than 1 and approached 2.5. The comparison between the number of events in each of the microseismic catalogues and their corresponding b-values is shown in Table 1. As the number of events in the catalogue decrease, the computed b-values increase.

Table 1. Formation b-value compared to the number of events in catalogue

Formation	Number of events in catalogue	b-value
Montney	11,790	1.05
Eagleford	9,839	1.09
Marcellus	4,267	2.01
Muskwa	4,403	2.30
Bakken	3,629	2.32
Barnett	1,981	2.45

Here, a b-value close to 1 indicates that there are relatively more large magnitude events in successively larger magnitude bins compared to the other formation with smaller catalogues. The

Marcellus, Muskwa, Bakken and Barnett formations have a relatively smaller microseismic catalogue and produced larger b-values. Likewise, a b-value closer to 2.5 indicates there are relatively smaller magnitude events in successively smaller magnitude bins compared to the larger event catalogues.

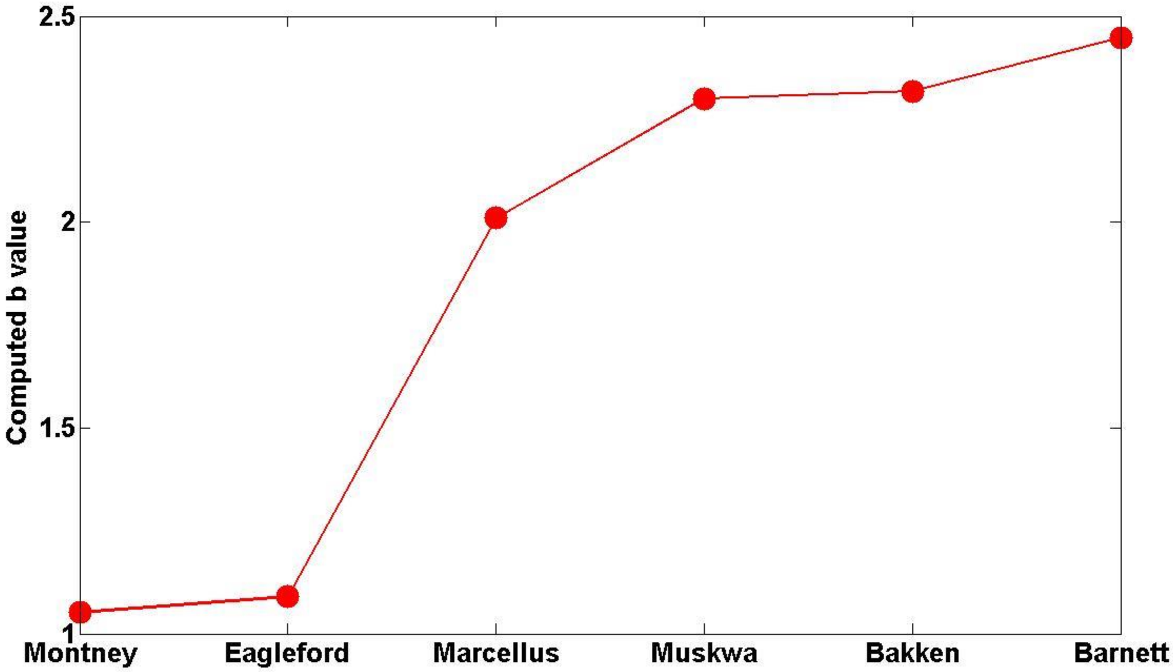

Figure 2: Computed b-values for various formations

The trend in Figure 2, which displays the computed b-value as a function of the total number of events in each catalogue, indicates that there can be a significant bias when not enough data is considered.

Conclusions

Comparisons between b-value and measurements derived from logs or fracture injection tests across different regions can provide valuable insight into the geomechanical behaviour of the rock.
In order to consider other influences on b-value such as rock properties, in-situ stresses, and weakness zones (i.e. natural fractures and bedding planes), a relatively large distribution of microseismic events is required. In this context, the number of events for the analysis of b-value needs to be statistically comparable across all regions.

Acknowledgements

Thank you to Norm Warpinkski, Dave W. Eaton and Hassan Khaniani for their useful and valuable discussions. I would also like to acknowledge Halliburton for supplying the data to perform this study.

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