Characterizing intrinsic and stratigraphic Q in VSP data with information measures, part II

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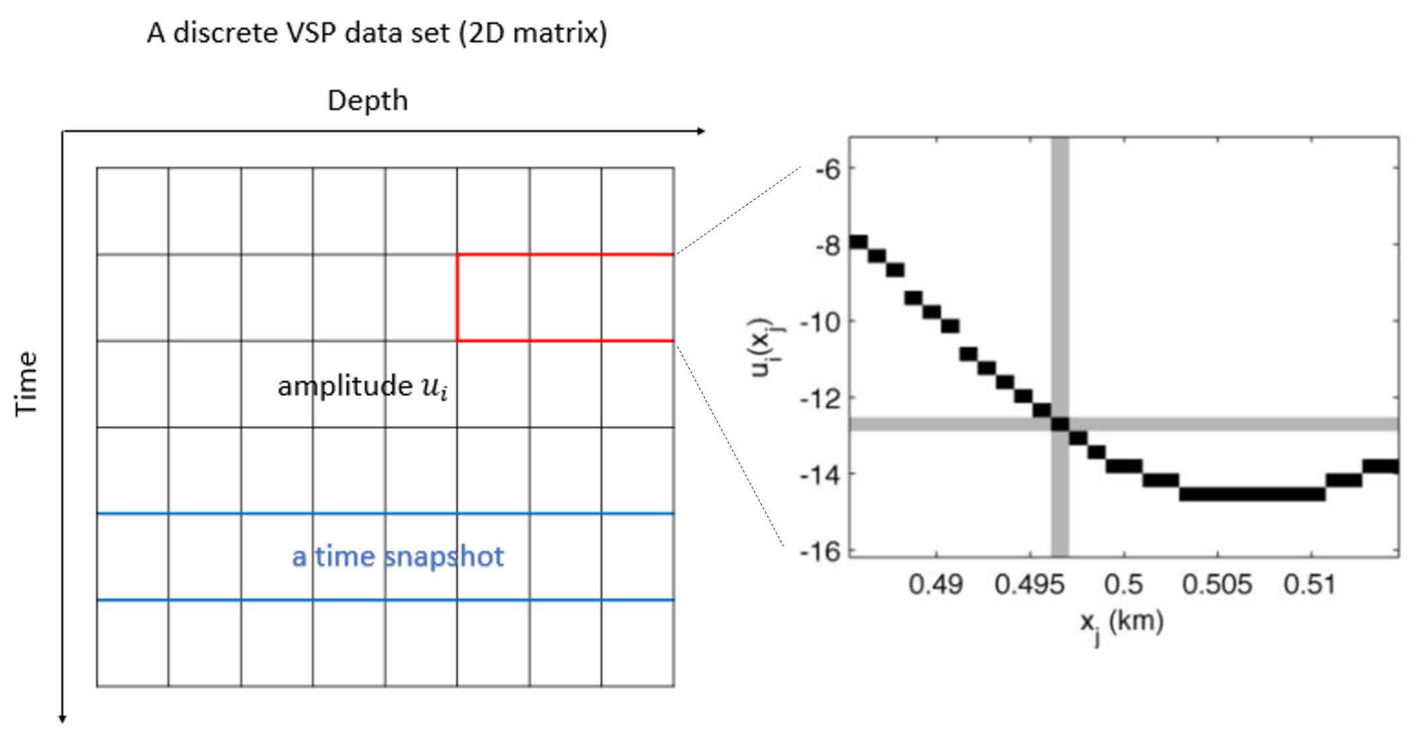
ABSTRACT

A Shannon entropy measure, used to measure the amount of information carried by a message in information theory, is adapted to the time domain synthetic VSP data, trying to distinguish between absorption (intrinsic Q) and stratigraphic filtering (extrinsic Q) which have similar amplitude attenuation and dispersion effects on seismic waves. Intrinsic and extrinsic Q are found to have seemingly opposite effects on entropy verses time result of the VSP data set. Thus, the measure entropy result of a VSP data set which is affected by both intrinsic and extrinsic Q, can, in some way, reflect the relative strength of two attenuation mechanisms when they act simultaneously on seismic waves.

First-order entropy measure on discrete VSP data sets

Algorithm



For a discrete VSP data set, assume each of its time snapshots to be a "message", and data points with amplitude u_i in the snapshot can be regarded as the "letters" which make up the "message".

Suppose each time snapshot consists of N data points (i.e. responses from N receivers), and every data point takes an amplitude value u_i $(i = 1,2, \dots, m)$. By enumerating the occurrences of a certain u_i in the snapshot as $W(u_i)$, define probability of its occurrence (Innanen, 2012) as:

$$P(u_i) = W(u_i) / \sum_{i=1}^{m} W(u_i).$$

And the first-order entropy of a single data point is:

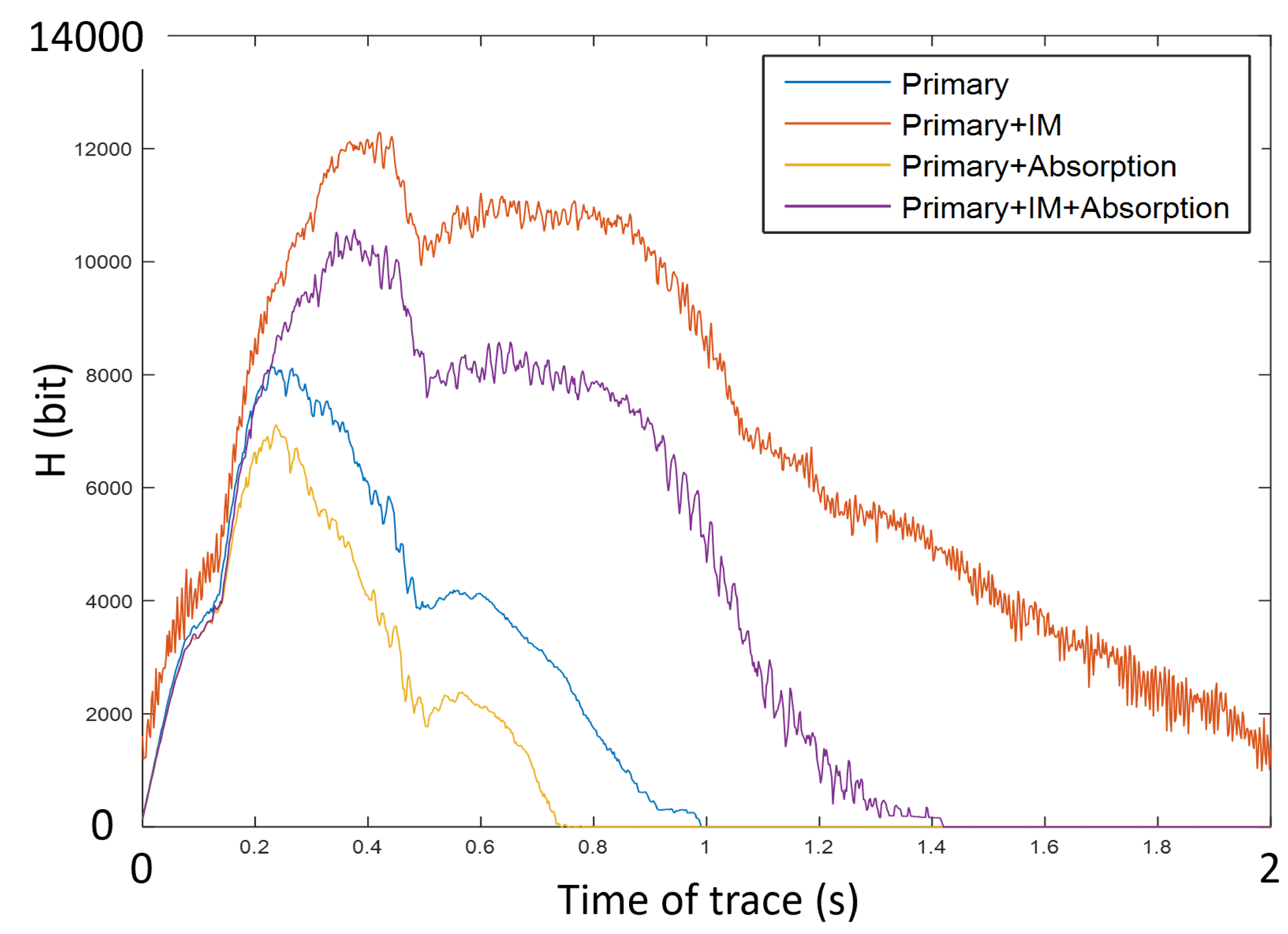
$$H' = -\sum_{i=1}^{m} P(u_i) \log_2 P(u_i).$$

The first-order entropy of a snapshot is:

$$H = N * H'.$$

The study investigates how entropy change (with time) among different snapshots of synthetic VSP wave fields which contain correspondingly: a) primaries; b) primaries with internal multiples; c) primaries with absorption and d) primaries with both absorption and internal multiples.

Well Blackfoot 1227 result



- For all situations, entropy increases with advancing time, reflecting the increasing amount of information in wave field; the entropy decrease is proven to be an artifact;
- Wave fields including internal multiples (purple and red curves) contribute to larger peak entropy values than other wave fields (blue and yellow curves);
- Entropies measured from wave fields containing absorption exhibit smaller peaks than others (comparing purple and yellow curves to the red and blue ones respectively);
- The most disordered wave field contributes to the largest entropy peak (red curve) and vice versa (yellow curve).

The information measure when both intrinsic and extrinsic Q are active

Intrinsic Q and extrinsic Q are likely to influence entropy in the opposite sense. Which gives promise in using the entropy behavior as an indicator of the relative strength of stratigraphic Q and absorptive Q, in scenario when their effects on a seismic wave are inseparable.

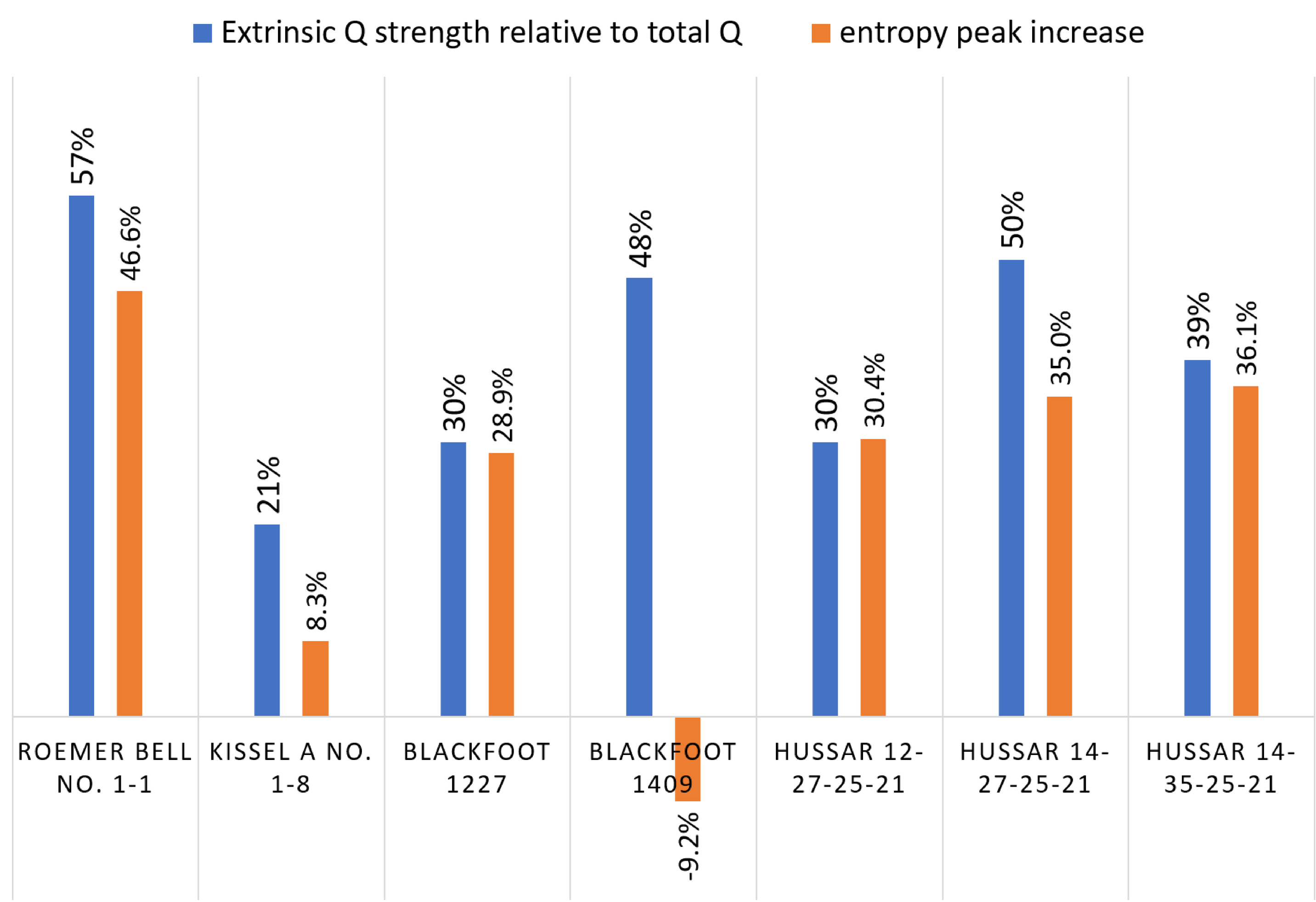
To test that, the entropy peak increase from wave field (a) to wave field (d) is calculated. Presumably, the stronger the strength of extrinsic Q relative to total Q is, the larger the entropy peak increase will be.

Utilizing the following relationship (Spencer et al., 1982) to estimate the extrinsic Q:

$$\frac{1}{Q_{apparent}} = \frac{1}{Q_{intrinsic}} + \frac{1}{Q_{extrinsic}}.$$

In which $Q_{intrinsic}$ and $Q_{apparent}$ are calculated respectively from wave field (c) and wave field (d) by the spectral ratio method.

Result of seven wells



Seven wells are tested.

- Roemer Bell No. 1-1 has the strongest extrinsic Q of all wells, and the largest entropy peak increase of all;
- Kissel A No. 1-8 has the weakest extrinsic Q and the smallest entropy peak increase;
- Similar positive relationship between extrinsic Q strength and the entropy peak increase are observed on well Blackfoot 1227 and three wells from Hussar working area;
- Blackfoot 1409 does not share the relationship. It is possibly that its Q was poorly estimated by the spectral ratio method due to a narrow frequency band this well has.

CONCLUSION

Among results of seven wells, six exhibit good agreement with the speculated relationship between extrinsic Q strength relative to total Q and the entropy peak increase from wave field (a) to wave field (d). Specifically, the stronger extrinsic Q is, the larger the entropy peak increase would be. It is inferred that whenever the entropy peak increase is negative, it could mean that the extrinsic Q strength in the research zone is considerably weak, likely to take less than 20% of total attenuation.

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