

The Investigation of the Spectral Decomposition Application in Detecting Reef Reservoir on Abadan Plain, Iran

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Abstract: Much of researchers (geophysical exploration) have focused on determining locations and geometries of subsurface accumulations as reefs petroleum reservoir that have unusual porosity and permeability. Spectral decomposition converts the seismic data from time to the frequency domain. One basic concept could be examining data in time domain at different frequencies and comparing and examining the response to provide significant insights to details. Each frequency in time domain make interferences pattern of layers respect to location of faults and changing bed thickness. Discrete Fast Fourier Transform (FFT) and Continuous Wavelet Transform (CWT) are the most common applied methods. Variations in spectral content occur due to the variations of the acoustic properties as bed thickness, and the nature of the interference between different layers. In this paper we try to apply frequency based attributes to highlight features like reef and interpretation of fault within data that otherwise is difficult to visualize. Spectral decomposition techniques have been performed as a quick and effective interpretation tool. FFT can provide good image from reservoir stratigraphic characteristic and CWT has good and clear image from reservoir structural characteristic. Spectral decomposition rather than 3D seismic data can provide clear visible image from internal details of a reef's extent. Based on images obtained from spectral decomposition, the results of this method is similar results of acoustic impedance inversion as regards acoustic impedance inversion method is expensive and time-consuming but spectral method can provide fast and suitable response for detect reef structure.

Key words: Spectral decomposition, geological properties, reef petroleum reservoir, extensional

INTRODUCTION

Much of geophysical exploration has centered on determining locations and geometries of subsurface reefs and other carbonate accumulations that have unusual porosity and permeability (Chopra, 2007). Overall reef geometry and pool dimensions can be interpreted accurately if the boundaries appear clearly. Accurate definitions of a reef's margins and internal porosity distribution determine trap definition and economic reservoir limits, which can be critical risk factors in making a carbonate, play viable. Although 3D seismic data almost can provide a good image of a reef's extent but internal details or (event edges) confines of reef often are not clear as until timeslices from the original seismic volume don't show the edges of the reefs clearly too. It isn't uncommon for wells drilled in mature basins to miss the optimal part of a reef because of insufficient or inaccurate imaging of the reef interior.

Geological Background and Data Base:

The structure of studied field is located in the south west of Iran in Abadan plain and surrounded by Dezful embayment, Khoramshahr and other structures in Abadan plain (Fig. 1). The structure is about 23 kilometers long and 9 kilometers wide and its trend (N-S) is an exception to the belt of foothill fold of

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southwestern Iran, striking NW-SE. The seismic data indicate the regional dip to the North–East and this field in Tertiary level is tilted towards north. Other study is based upon a database including 3 exploration wells and 3D seismic cube in this field. The area is quite flat and covered by quaternary alluviums and this zone is not seismically active as almost there is no evidence of geological outcrops for subsurface structures, therefore seismic data and the results of drilled wells are key tools in detection of subsurface features. The Abadan plain including this structure is situated within Mesopotamian foredeep basin in southwest of the Zagros foreland and foredeep basin area contains many super giant oil and gas fields (Berberian, 1995). Regional unconformities in Cretaceous age (for example erosional surface in the top of Fahliyan Formation) could be related to the early stages of compression during the initiation of convergence and closure of the Neo-Tethys Ocean. It is parallel to an N-trending anticline which extends from Saudi Arabia to Kuwait's Burgan field (Al-Husseini, 2000).

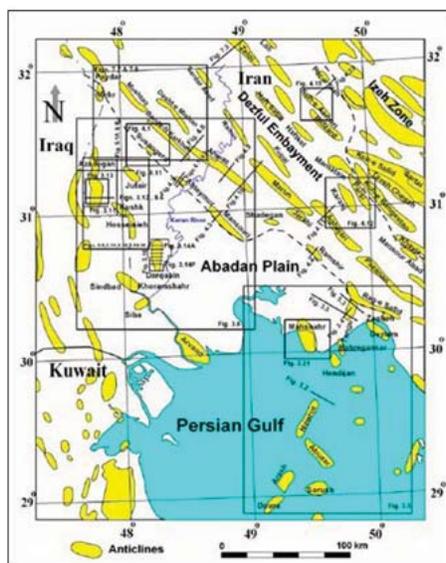


Fig. 1: Location of field structure (Abdollahi Fard, 2002).

Geological setting of structure:

The Early Cretaceous 'Garau intra-shelf basin' inherited much of the differential topography from the earlier Jurassic Gotnia intra-shelf basin (Sharland et al., 2001) in the Abadan Plain and Dezful embayment. Later on progressive uplift of the western Arabian plate area (including Abadan Plain) commenced, possibly as a result of the opening of the south and central Atlantic Ocean (Sharland, 2001) and most of the area was dominated by shallow water deposition of carbonate ramp (Fahliyan formation). The Neocomian Fahliyan formation is subdivided into two parts in SW Iran. Upper Fahliyan (Ratawi equivalent) has more or less basal facies but Lower Fahliyan (Yamama equivalent) has shelf carbonate facies and this part is main reservoir of structure. The lower part is equivalent to the Yamama-Minagish in Kuwait and SE Iraq. Ziegler (2001) suggested a shelf platform of the Arabian plate that was covered by shallow-water carbonates Yamama during the Berriasian to Valanginian (144-132 Ma). Also Sadooni *et al.* (2001) proposed sedimentation of Yamama formation in SE Iraq on a leeward ramp on the gentle slope of the Arabian Platform. The interpreted horizons and stratigraphic column of this field could be seen in Fig. 2.

Fahliyan formation:

Fahliyan Formation is main reservoir in this structure. It subdivided into two members. Upper Fahliyan (Ratawi equivalent) has more or less basal facies but Lower Fahliyan (Yamama equivalent) has shelf carbonate facies and this part is main reservoir of structure. Two horizons were interpreted (Top and pay zone) in Fahliyan Formation and it seems pay zone is top Lower Fahliyan. Top Fahliyan horizon is almost a discontinuous reflector but interpretation of pay zone is easier than top Fahliyan, especially at western flank of this structure. The occurrence of onlap in the top of Fahliyan formation (Fig. 3) shows a shallow-water environment that depends on a relative rise of base level to allow the carbonate "factory" to go into production. This is found in back-stepping reefal environments due to subsidence and shelf areas that undergo subsidence.

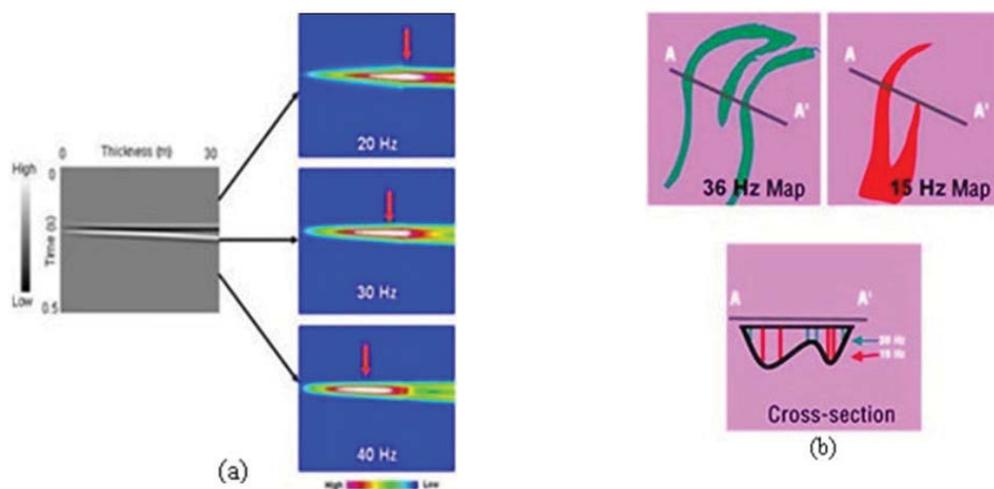


Fig. 4: (a): Relation between tuning thickness and frequency (Liu, 2007) and (b) representation results of spectral decomposition at 36 Hz, 15 Hz maps and channel thickness detect with variable frequency (Chopra, 2007). Low frequency slices indicate high thickness (green lines) and high frequency slices indicate low thickness of geology event (red lines).

The effect of application shows the tuning frequency event in edges and boundaries of the reef structure (Fig. 5). Onlap system track and its pinch out in the edges of reef create these tuning frequencies as with temporal thickness or (temporal) thickness of pinch out of edges reef decrease, tuning frequency increase inversely. If various frequency are animate, it could be thickness propagation in spectral decomposition result map.

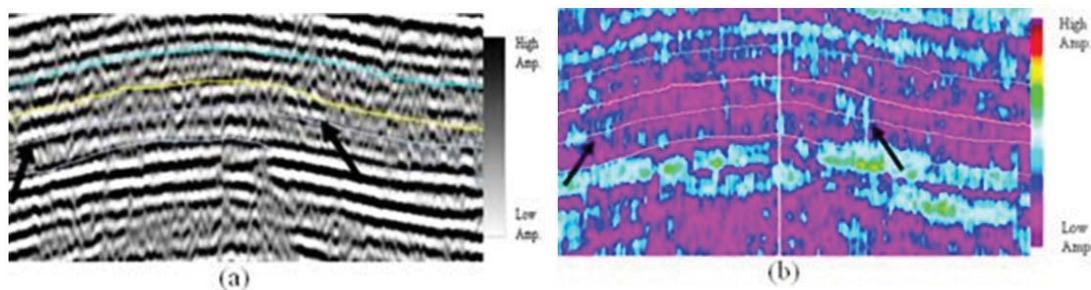


Fig. 5: (a): Seismic section and (b) its FFT section in frequency 15 Hz. Black arrows indicate edges of reef and the boundaries of reef in environs of reef are distinct too.

RESULTS AND DISSCUSION

Representation difference between seismic and spectral decomposition at a timeslice whereas seismic can't show clear images, spectral decomposition provide clear image from reef structure (Fig. 6). Spectral decomposition method indicates ellipse anomaly from this reef structure and it indicated one dense (low porosity) at western part of structure too (Fig. 6 & 12).

The edge of reef has low and internal structure of reef has high frequency content but due to limitation of frequency, in this project the reef and fault structure could be studied in high frequency. This work has been done with filtering seismic data (scale filtering) in specific range because that increase contrasts of layers. Hereto frequency range is limit as representation spectral analysis of seismic data in one section in this project as the frequency range almost is from 10 Hz to 50 Hz (Fig. 7) and it could not study very high frequency signals that created by fault are weak and low amplitudes of signals in low frequency. Morlet wavelet in CWT method has poor vertical resolution (Castagna and Sun, 2006) and this property is suitable for fault detection and perhaps help to better to show this event in lithological changes.

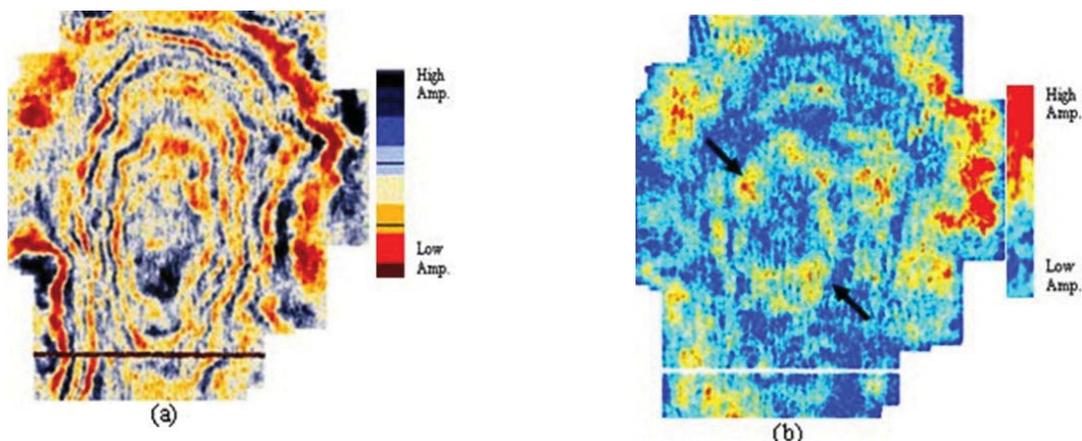


Fig. 6: Representation of a timeslice (a) seismic and (b) spectral decomposition (FFT method) in frequency 14 Hz. Black arrows show reef boundaries.

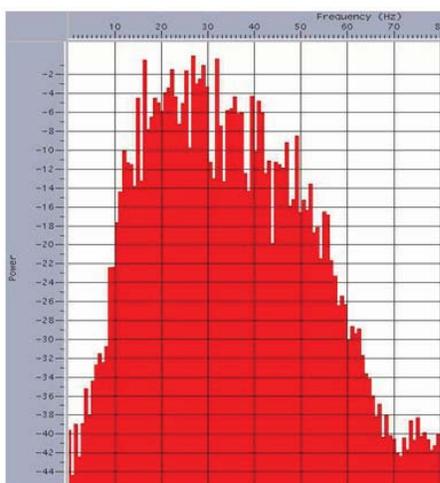


Fig. 7: This figure shows spectral analysis of seismic section. Horizontal axis is frequency (Hz) and vertical axis is power (db). Power in frequencies out of 10-50 Hz is very weak and venial.

Compare between spectral decomposition methods:

A comparison between FFT and CWT method in a same timeslice could be distinguished these two methods in representation stratigraphic and tectonic properties of reservoir (Fig. 8). At this figure, extensional systems with CWT method can provide good image rather than FFT method and this system indicates with red arrows whereas ability of FFT method is get good imaging from stratigraphic structure (part (a) & (b) at Fig.8).

With pay attention to spectral decomposition results, it could be interpreted the situation of top and base of reef and extract its geometry (Fig. 9) as this figure represents the horizon grid of top and base reef's structure with effective extensional systems on reservoir part and the thickness map of this reef structure as showed high and low thickness locations and sedimentation (accumulation of sediments) in basin have highest thickness toward south of Persian Gulf (Fig. 10).

Compare between other data:

These results correlate with results obtained from wells in reservoir perfectly as at center of reservoir in well-2 location (that spectral decomposition showed high thickness), oil column is 100 m and in well-3 location at the west of reservoir, oil column is 10 m. Therefore using the results of spectral decomposition in detecting reef structure and extensional (fault) systems and drilling in highest thickness reefs and toward extensional

systems (for example drilling injection wells for oil recovery), operators can improve oil production amount and increase oil recovery from this reservoir for next process. The log data (sonic log) from wells in reservoir have good correlation with spectral decomposition results (Fig 11). If top and base of reef, extensional systems and log data (gamma-ray and porosity logs) are combining, then interpreter can has good view and clear understanding from reservoir properties (Fig. 12).

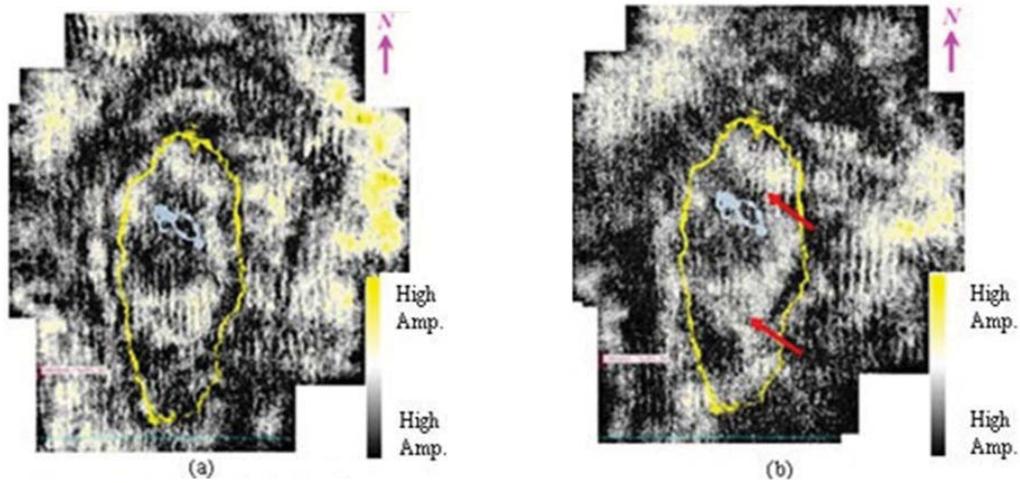


Fig. 8: Comparison between (a) FFT with (b) CWT in direct extensional system at same timeslice. At this figure, extensional systems that indicate with red arrows by CWT can provide good image rather than FFT.

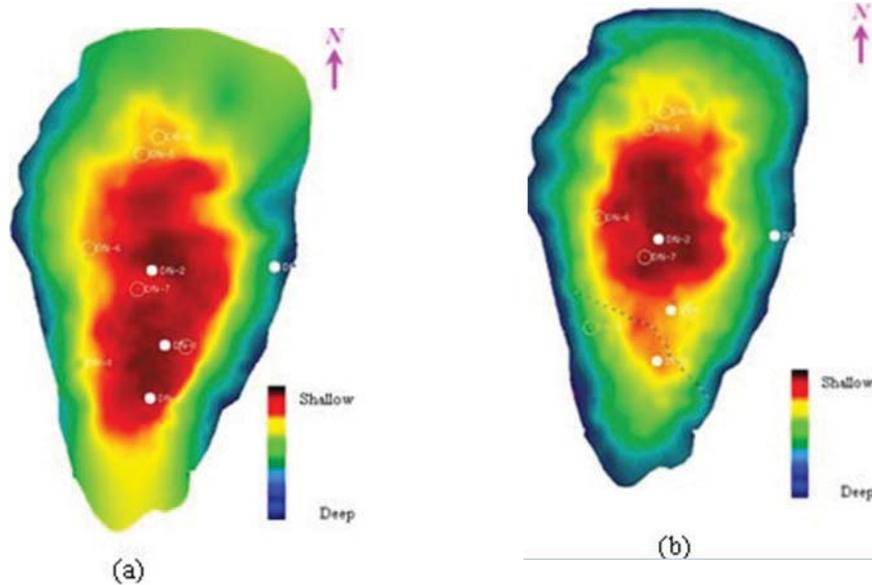


Fig. 9: Time grid maps (a) top and (b) base of reef with tectonic system direction and location of wells at reservoir.

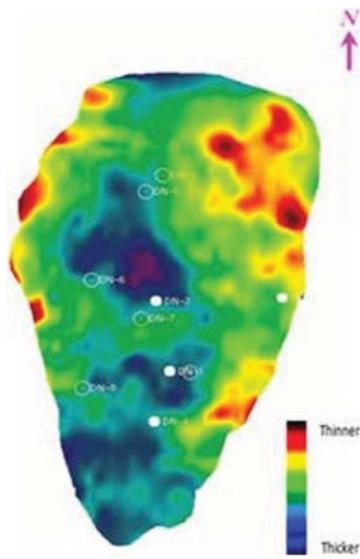


Fig. 10: Thickness map of reef.

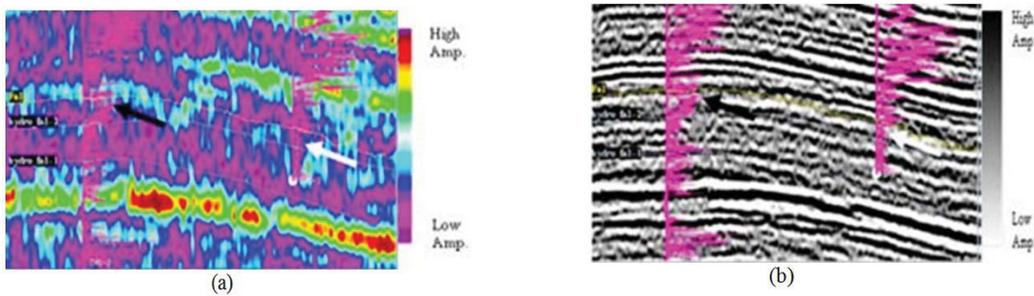


Fig. 11: Sonic logs at two wells in Fahliyan reservoir. (a) Seismic section (b) spectral decomposition result. Black arrow indicates high porosity in well-2 (left) and white arrow indicates low porosity in well-3 (right). Part (b) shows the edge of reef in location well-3 and top of reef at top black arrow. Well-2 located at mid of reef too and small amount anomaly in location well-2 indicates the center of reef structure.

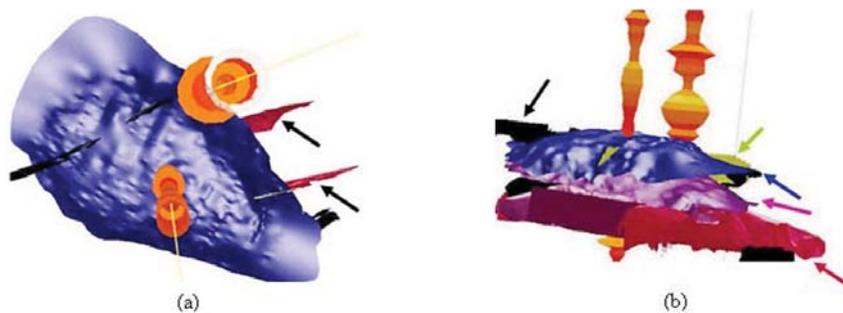


Fig. 12: Map top and base of reef and logs with extensional systems (Top of reef, base of reef and top of Hydrofahliyan1 from up to down consequently with combine porosity and gamma-ray logs of wells 2 & 3 and arrows indicate extensional system too).

Acoustic impedance inversion is other study at this reservoir. Inversion method done by Maleki *et al.* (2006) and it result is same with result of spectral decomposition method as at part west of structure, reservoir has low porosity and edge of reef structure is appearance in result two method (Fig. 12) and located in west of reservoir has low oil column.

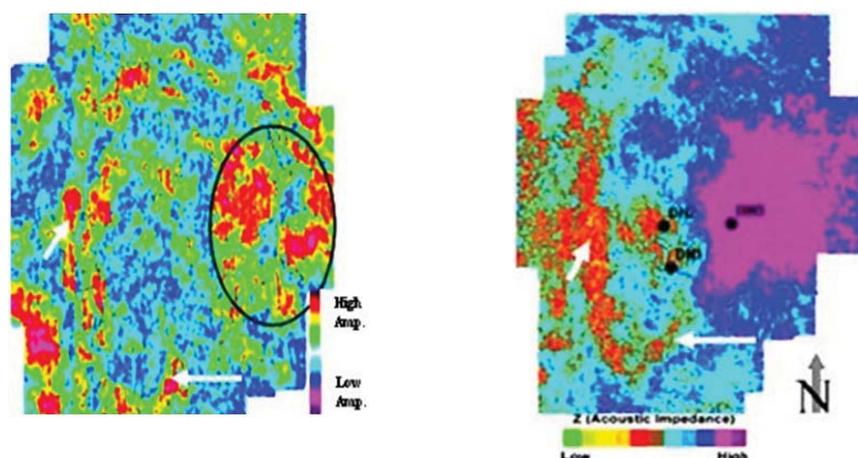


Fig. 13: Comparison between results of (a) FFT method and (b) inversion method at a timeslice (Maleki, 2006). At this figure, black ellipses indicate low porosity area and with white arrows by FFT method can provide good image from edge of reef.

Conclusions:

Much of geophysical exploration has centered on determining locations and geometries of subsurface reefs and other carbonate accumulations that have unusual porosity and permeability although 3D seismic data could provide a good image of a reef's extent, but internal details often are not clear whereas use from spectral decomposition can provide clear and good visible image of reef structure on petroleum reservoir.

It is not uncommon for wells drilled in mature basins to miss the optimal part of a reef because of insufficient or inaccurate imaging of the reefs interior. Accurate definitions of a reef's margins and internal porosity distribution determine trap definition and economic reservoir limits, which can be critical risk factors in making a carbonate, play viable. The use of 3D volumetric attributes, as spectral decomposition and acoustic impedance inversion, helps us map these subtle heterogeneities.

Spectral decomposition show the frequency content of signals as it gives (disposal) to researchers' and engineers suitable view from reservoir properties petroleum.

Look at figure 7, we could compare between two methods of spectral decomposition i.e. FFT and CWT. At this figure FFT can provide good images from reservoir stratigraphic characteristic whereas CWT has good and clear images from reservoir structural characteristic rather than FFT. Thereupon spectral decomposition various methods can provide suitable information from geological characteristics for study reservoir or other study for geologists and drilling operators.

Based on images obtained from spectral decomposition, the results of this method is similar results of acoustic impedance inversion as regards acoustic impedance inversion method is expensive and time-consuming but spectral method can provide fast and suitable response for detecting reef structure.

Abadan plain has good potential from petroleum accumulation, therefore spectral decomposition method study in other formation and reservoir at this region is useful and effective for detect reservoir as reef and that give us a fast evaluation from other reservoir.

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