Whatu Raranga a Kiwa, Understanding and Uniting Māori and Pacific Textiles.

Methods for identifying plant materials in Māori and Pacific textiles

Bronwyn Lowe and Catherine Smith

Department of Applied Sciences (Clothing and Textile Sciences), University of Otago, PO Box 56, Dunedin. Corresponding author: bronwyn.lowe@otago.ac.nz

Abstract

Investigating the range of plant species used in Māori and Pacific textiles can help to understand the diversity and relationships among whatu and raranga techniques and art forms. Although the style and construction of Māori and Pacific textile artefacts often give clues as to the plant species used, positive species identification is not always possible from visual inspection. This may be due to the age and condition of the artefact, or effects of leaf processing such as splitting, softening, stripping or dying. A range of laboratory methods and published resources are however available to help with the identification process. Understanding the internal and surface anatomy of raw leaf material (e.g. Carr and Cruthers 2007; Carr et. al. 2009), the effects of leaf preparation for weaving on leaf anatomy (e.g. King 2003) and the expected condition of specimens sampled from artefacts can aid the interpretation of data collected in the laboratory. The most appropriate method of specimen preparation is another important consideration. This paper provides a review of microscopy and tomography techniques and on-line resources, which have been trialled and implemented in the Clothing and Textile Sciences Department at the University of Otago for the identification of plant species of interest in New Zealand and the Pacific. The advantages and disadvantages of these techniques and resources for identifying plant materials in artefacts will be discussed.

Introduction

A wide range of plant materials are used in Māori and Pacific textiles, including whole leaves, leaf strips and fibre extracted from bark and leaves. These materials are sourced from a variety of plant species. Identifying the plant species used in textile artefacts has a number of benefits; it can add to understanding of the diversity and relationships among whatu and raranga techniques and art forms, it can assist with researching the provenance of artefacts held in cultural institutions and private collections, and it can help conservators select and apply appropriate conservation treatments. A number of laboratory methods are available for identifying plant material in artefacts, ranging from relatively simple macroscopic techniques to more complex microscopic techniques. Successful species identification depends on familiarity with the diagnostic features that can be detected with the different techniques. It also depends on awareness of factors that may limit the usefulness of diagnostic features, such as natural variability inherent in plant materials, the effects of sample preparation, and how diagnostic features may have been altered during manufacture, use and aging of the artefact. The following discussion provides an overview of methods used to identify plant species in textile artefacts in general, and discusses examples of methods that have been used in the University of Otago Department of Applied Science (Clothing and Textile Sciences) for identifying plant species used in Māori and Pacific textiles in particular.

Factors to consider before choosing an identification method

The choice of appropriate methods for identifying plant material used in an artefact depends on the purpose of the investigation, the level of desired taxonomic detail, ethical or practical constraints on artefact sampling, the availability of equipment and expertise, and of course, the costs relative to the information gained.

The purpose of an investigation must be made clear before an identification method can be chosen. Factors such as why or for whom the investigation is being done, who will use the information collected, and what will happen to the information once the project is complete may all have ethical or cultural implications affecting the choice of method. The acceptability of obtaining samples of plant material from the artefact should also be considered in an ethical and cultural context.

The purpose of the investigation will also dictate the level of taxonomic detail required. It may only be necessary to identify the plant material to family or genus, for example harakeke (*Phormium*) compared with kiekie (*Freycinetia*). If the geographic provenance of the artefact is in question, then identifying different species, or varieties within a species, is more important. In other cases, the part of the plant may be of interest, for example whether leaf, bark, root or fibre, or a combination of these have been used in the construction of an artefact. As the level of taxonomic detail required increases, positive identification becomes more difficult. Differences between samples may be subtle, and identification methods with higher resolution of microstructural details (Figure 1) are needed to detect the differences.

Constraints on sampling from the artefact can dictate the choice of identification method. There may be ethical or cultural reasons for refraining from sampling at all, in which case identification relies on visual inspection of the intact artefact. There may be practical constraints, for example the plant material in the artefact may be so delicate or degraded that any sample would be too unstable to work with. The sampling method itself may have unacceptable implications, for example damage to the artefact, or irreversible alteration of the sample as it is prepared for analysis (Table 1). The use of fragments that have previously detached from an artefact is a less invasive or damaging alternative to direct sampling, but relies on the assumption that the fragment came from the artefact itself.

Overview of identification methods

The methods available for identifying plant species in Māori and Pacific textiles are the same as those used for other textiles (Florian, Kronkright and Norton 1997) and range from relatively inexpensive and simple techniques at the macroscopic scale, through to expensive, technically complex but high resolution techniques at the microscopic scale (Figure 1). At the macroscopic scale, the relatively straightforward methods of visual inspection using the naked eye, a hand lens or a stereomicroscope can be used. Usually the artefact is inspected as a whole, with features such as the style and construction giving clues as to the plant species used. Comparison with artefacts constructed from known plant materials and consultation with practicing artists can assist with identification.

Optical microscopy, using tools such as stereo, compound and polarising microscopes enables the anatomy of plant materials to be investigated (Florian, Kronkright and Norton 1997). Compound and polarising microscopy both require special sample preparation in order to observe thin cross-sections of the material (Table 1). Sample preparation for stereomicroscopy simply involves ensuring the sample is a suitable size to be placed under the lens. The type of optical microscope used determines the size of anatomical features that can observed. For example, stereomicroscopes are good for observing features from centimetre size down to a few hundred microns, whilst a good compound or polarising microscope can resolve features less than 10 microns in size.

X-ray computed tomography is a technique that has only relatively recently been applied to examining textile artefacts. The range of features observable is similar to that in optical microscopy, but an added advantage is three-dimensional visualisation of the internal structure of a sample (O'Connor, Brooks, Fagan et al. 2008). Micro-computed tomography is particularly promising for analysing smaller anatomical features of plant materials, from millimetre size down to the scale of 10s of microns.

Scanning electron microscopes (SEM) provide three-dimensional images similar to stereomicroscopes, but are capable of much higher magnification. The three dimensional morphology of microstructural features less than a micron in size can be observed. For example calcium oxalate crystals present as inclusions within plant tissues (Bergfjord and Holst 2010; Carr, Cruthers, Girvan et al. 2008) and waxes on the surface of leaves (Carr, Cruthers, Girvan et al. 2009) have in some cases been used to discriminate among plant species.

Infra-red spectroscopy and x-ray micro diffraction enable subtle differences among plant fibres to be detected at the cellular level. Plant fibres consist of many long, thin cells in which the main chemical component is cellulose. Cellulose molecules are aligned in a spiral along the length of a cell, and their angle to the cell axis, the direction of the wind and their crystallinity are all diagnostic for some species. These characteristics have been used to discriminate among flax, jute, sisal and ramie fibres (Bergfjord and Holst 2010; Garside and Wyeth 2007; Muller, Murphy, Burghammer et al. 2006), but the same level of knowledge is not available for plant fibres traditionally used in Māori and Pacific textiles. The arrangement and crystallinity of cellulose molecules can also be detected using polarising microscopy (Bergfjord and Holst 2010). X-ray micro diffraction is the most complex and expensive of the techniques mentioned here, as it is usually carried out using a synchrotron (Muller, Murphy, Burghammer et al. 2006).

All of these methods involve physically handling an artefact, and almost all will alter the artefact in some way, as they require a sample of material (Florian, Kronkright and Norton 1997). The amount of material sampled depends on the method being used, but small pieces, for example individual fibres or leaf fragments are often adequate. Preparation of samples for analysis often irreversibly alters or even destroys the sample, depending on the identification method (Table 1).

Not all of these methods have been applied to investigating plant materials in Māori and Pacific textiles. Characteristics such as the crystallinity and arrangement of cellulose molecules in fibre materials are not well known, apart from some limited investigations of harakeke (Duchemin and Staiger 2009). To date, optical microscopy, scanning electron microscopy and micro-computed tomography are methods that have been trialled and implemented in the Department of Applied Sciences (Clothing and Textiles Sciences).

Recognising diagnostic features of leaf and fibre material

Familiarity with microstructural features of leaf and fibre material from different plant species is essential for successful species identification. The general anatomy of most plant species used in textiles is well documented (Florian, Kronkright and Norton 1997). Many of the plant species used in Māori and Pacific textiles are monocots, characterised by long thin leaves strengthened by veins of vascular and fibrous tissues running the length of the leaf. When viewed in cross-section under a microscope, the shapes, arrangement and size of the vascular and fibrous tissue are distinctive for different species (Carr and Cruthers 2007; Smith, Lowe, Blair, et al. submitted 2011). For example harakeke leaves have large, distinctively shaped fibre bundles in the upper surface of the leaf (Figure 2). A useful on-line resource for gaining familiarity with the leaf anatomy of New Zealand and Pacific plants is an atlas of plant materials published by the University of Otago Department of Applied Sciences (Clothing and Textile Sciences) (Carr and Cruthers 2007, and see http://www.otago.ac.nz/textiles/plantfibres/index.html). Leaf material from different species can also be recognised by the appearance of the leaf surface including the patterns, density and size of veins in the leaf (Carr and Cruthers 2007). The morphology of surface waxes (e.g. Figure 3a and b) have been documented for a limited range of plants (Carr, Cruthers, Girvan et al. 2009). Small calcium oxalate crystals (approximately 10 µm in size) within plant leaf tissues are also considered diagnostic, although there is some debate about how reliable they are for discriminating among species (Bergfjord and Holst 2010, Carr, Cruthers, Girvan et al. 2008).

Fibre materials from some plant species can be distinguished by observing microscopic features of individual fibre cells, known as ultimate fibres. Differences in length and width, the shape of the fibre tip, longitudinal features such as nodes, appearance in cross-section and the presence or absence of particular types of calcium oxalate crystal have all been discussed as tools for species identification in textiles (Florian, Kronkright and Norton 1997; Bergfjord and Holst 2010; Bergfjord, Karg, Rast-Eicher, et al. 2010) including Māori and Pacific textiles (Carr, Cruthers, Girvan et al. 2008; King 2003). For example, polarised microscopy techniques have been used to successfully discriminate among bast fibres (European flax, nettle, ramie, hemp and jute) based on the presence or absence of crystals of particular shapes (Bergfjord and Holst 2010).

Limitations and solutions

Although much is known about the anatomy and microstructural features of leaf and fibre material from different plant species, positive identification of materials in textiles can be notoriously difficult for two reasons. Plant materials are naturally highly variable, and diagnostic features can be profoundly altered by the effects of textile manufacture, aging and sample preparation.

The natural variability in plant materials is due to factors such as genetic variation within species, variations in growing conditions, and the maturity of the plant or plant part at the time of harvest. As a result, the range in size and shape of some diagnostic features can overlap considerably among species and varieties. This is most problematic among species with similar anatomy, for example bast fibre plants such as European flax, ramie, jute and hemp (Bergfjord and Holst 2010), and the monocots used in Māori textiles, such as tī kōuka and harakeke (Smith, Lowe, Blair et al. submitted 2011). The many varieties of harakeke (Scheele 2005) in particular exhibit a wide range of fibre bundle size and shape in leaf material (Lowe 2011) (e.g. Figures 2a, b and c). Careful sampling designed to explore the expected variability can go some way toward solving the problem of overlap in diagnostic features (Smith, Lowe, Blair et al. submitted 2011).

Processing of plant materials for textile manufacture alters their diagnostic features from the raw or harvested state in a number of ways. Leaf materials may be split into strips, softened by applying pressure, boiled and dyed. Fibres may be extracted from leaves, stems or roots by stripping, retting or pounding, and further processed by washing, pounding and dying. Characteristic alterations to the anatomy and microstructure of plant materials can help with identifying methods of artefact manufacture, but can simultaneously mask diagnostic features for species identification. For example, softening and boiling of harakeke leaf strips can obliterate the identifying morphology of surface waxes (Lowe 2011) (Figure 3c and d).

Preparation of cross-section samples for optical microscopy can introduce flaws or damage that may be confused with the effects of processing plant materials for textiles. Leaf tissues or fibres may shrink, swell, change shape or even disintegrate completely, depending on the chemicals and temperatures used. Slicing cross-sections thin enough to be viewed in a compound or polarising microscope may disrupt or distort the tissues further. For example, evidence of the blade used to prepare the harakeke samples in Figure 2 can be clearly seen as striations across the fibre bundles in Figure 2c, and are not a product of processing for textile use.

Micro-computed tomography is a promising technique for species identification that avoids some of the problems associated with sample preparation, and has recently been trialled in the University of Otago Department of Applied Science (Clothing and Textile Sciences) (Smith et al. submitted 2011). Advantages of this technique are that samples do not need to be mounted and sliced in order to observe cross-sections, and entire specimens can be examined in the same state as sampled from the artefact. X-ray data collected from the sample is processed by a computer to generate a three-dimensional model of the sample. Using software, virtual cross-sections can be visualised at any chosen position and angle within the body of the sample (Figure 4). This allows some of the variability within a sample to be explored, and cross-sections with the least alteration or most recognisable anatomical or microstructural features to be selected for species identification.

Conclusion

A number of different methods are available for identifying the plant materials used in Māori and Pacific textiles. Each method provides information at a different scale and resolution, and the choice of appropriate method depends on the level of taxonomic detail desired. Species identification requires familiarity with the anatomical and microstructural features characteristic of each species, as well as the effects that manufacturing, use and aging has on plant materials in textiles. Although some of the characteristic features of Māori and Pacific plant materials have been documented in their raw or unprocessed state, the effects of processing and aging on these features when used in textile artefacts has only recently begun to be documented.

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Author biographies

Bronwyn Lowe is a lecturer, Department of Applied Sciences (Clothing and Textile Sciences), University of Otago, where she teaches identification and properties of fibres, yarns and fabrics and the physical relationships of clothing to the body. She has qualifications in both Materials Engineering and Environmental Science. Bronwyn brings this blend of expertise to her research, and enjoys participating in multi-disciplinary projects. In 2010 she completed a postdoctoral fellowship investigating mātauranga Māori and western science methods for identifying varieties of harakeke (New Zealand flax) used for traditional Māori weaving. Important elements of this project were consultation and collaboration with the weaving community and communication of research results through a series of public hui.

Catherine Smith is a lecturer, Department of Applied Sciences (Clothing and Textile Sciences), University of Otago, where she teaches social and historical aspects of dress. She is a conservator of cultural material (ethnographic artefacts), is past President of the New Zealand Conservators of Cultural Material (NZCCM) and has worked as a consultant and conservator for numerous museums in New Zealand and Australia. Catherine's research interests include pre-contact Māori textiles, and the ethics and practice of conservation with specific focus on consultative and interdisciplinary activities.

Table 1. Identification methods and sample preparation for plant materials in textile artefacts. Sampling involves removing a representative piece, referred to as the sample, from the artefact, the size of which depends on the method. Samples may need further processing prior to analysis.

Method	**Sampling required**	**Sample processing**
Visual inspection	None	None
Hand lens	None	None
Stereo microscopy	Depends on artefact size relative to microscope, if bulky or delicate, may require sampling. Single fibres	None if only surface features being observed. Can observe cross-sections
X-ray computed tomography	Small leaf material sample (mm's), or single fibres	None
Compound microscopy	Small leaf material sample (mm's), or single fibres	Sectioning, mounting on microscope slide
Polarising microscopy	Small leaf material sample (mm's), or single fibres	Sectioning, mounting on microscope slide
Scanning Electron Microscopy (SEM)	Small leaf material sample (mm's), or single fibres	Adhesion to microscope stub, coating with conductive metal layer
Spectroscopy (FTIR)	Small leaf material sample (mm's), or single fibres	None (if single fibre), or ground to powder
X-ray microdiffraction	Small leaf material sample (mm's), or single fibres	None (if single fibre), or ground to powder

Figure captions

Figure 1. Methods available for identification of plant species in textile materials and artefacts. Increasing resolution and detail is achieved with increasing complexity and cost of equipment and techniques.

Figure 2. Optical micrographs of leaf cross-sections from three different varieties of harakeke (*Phormium tenax*). Fibre bundles appear as white shapes in repeating patterns across the cross-section. All cross-sections prepared from fresh leaf samples prior to any processing for weaving. (After Lowe 2011.)

Figure 3. Scanning electron micrographs of leaf surface wax on two different harakeke (*Phormium tenax*) varieties. a) and b): Samples prepared from fresh leaf samples prior to any processing for weaving. c) and d): The same leaf samples after softening and boiling. (After Lowe 2011.)

Figure 4. Micro-computed tomography image of kiekie (*Freycinetia banksii*), showing the intersection of virtual cross-sections in the x, y and z planes. (Image collected by Kate Blair.)

Identification methods for plant materials

Macroscopic features
- Visual inspection
- Hand lens

Microscopic features
- Stereo microscopy
- X-ray-computed tomography
- Compound microscopy
- Polarising microscopy
- Scanning electron microscopy

Molecular structure/crystallinity
- Infra Red Spectroscopy (FTIR)
- X-ray micro-diffraction (synchrotron)

↓ Increasing resolution, detail

Increasing complexity

Increasing cost

Fig 1

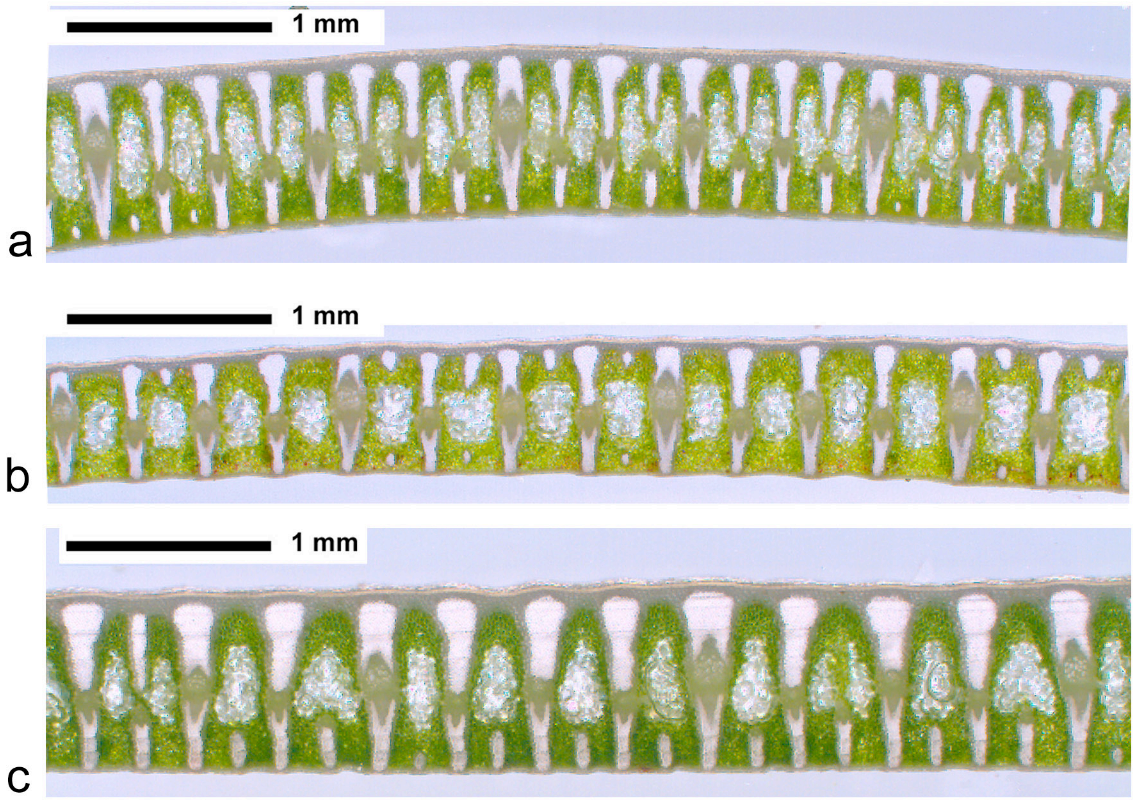

Fig 2

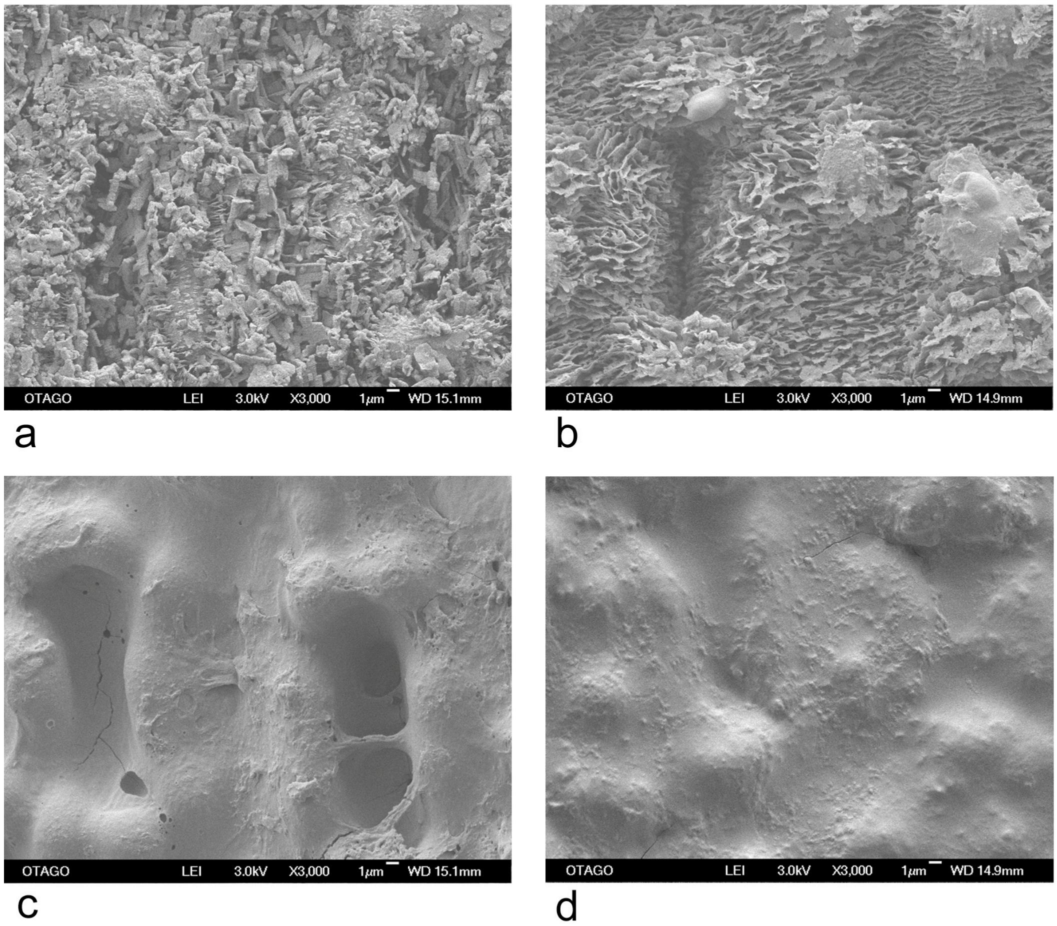
OTAGO LEI 3.0kV X3,000 1μm WD 15.1mm
a
OTAGO LEI 3.0kV X3,000 1μm WD 14.9mm
b
OTAGO LEI 3.0kV X3,000 1μm WD 15.1mm
c
OTAGO LEI 3.0kV X3,000 1μm WD 14.9mm
d

Fig 3

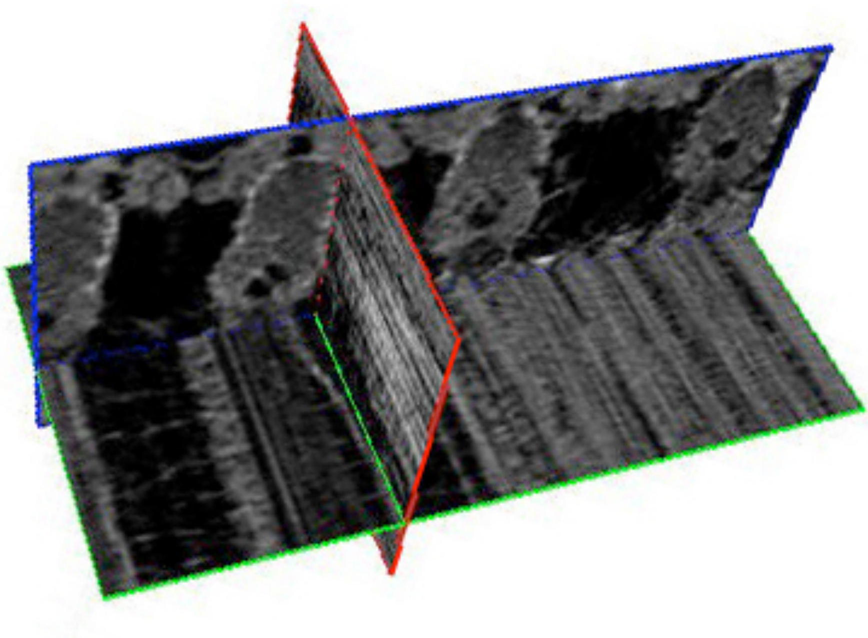

Fig 4