REPRESENTATION IN KNOWLEDGE-BASED SYSTEMS

Reid G. Smith

Schlumberger-Doll Research
Old Quarry Road
Ridgefield, CT 06877-4108
USA

AI Europa, Wiesbaden, Germany, September, 1985.

EXTENDED ABSTRACT

First generation knowledge-based systems (KBSs) typically used a single representational paradigm–such as production rules–to meet all requirements. More ambitious goals have led largely to the abandonment of this simple model. These goals include: *(i)* construction of systems that encapsulate more aspects of human expert behavior; and *(ii)* reduction in the cost of system construction and maintenance; and *(iii)* improvement of time/space performance. As a result, current systems tend to use multiple representations–such as objects, rules, constraints, tasks, and procedures–each tuned to handle specialized classes of information and situations. A number of designers have found it advantageous to integrate the different paradigms via an object-oriented foundation, or *substrate*.

To understand the utility of an object-oriented substrate, we consider the process of KBS development. In current practice the transfer of expertise from a domain specialist to a knowledge-based system involves a computer scientist intermediary–or *knowledge engineer*. The specialist and the engineer discuss the domain in a series of interactions. During each interaction, the engineer gathers some understanding of a portion of the specialist's knowledge, encodes it in the evolving system, discusses the encoding and the results of its application with the specialist, and refines the encoded knowledge. The process is a painstaking one–expensive and tedious. As a result, one of the foremost problems that has been identified for KBSs is the *knowledge acquisition bottleneck*.

For our purposes, we can observe that two sorts of software tools and methods are crucial to a smooth KBS development scenario: *(i)* those that simplify the process of incremental system refinement; and *(ii)* those that allow the domain specialist to interact directly to some extent with the evolving system in order to: examine the knowledge base for gaps, weaknesses, and misunderstandings; and expand, refine, and correct the encoded knowledge. Such tools have the potential to increase the bandwidth of the interaction between domain specialist, knowledge engineer, and system by allowing attention to be focused on the required domain knowledge and problem-solving methodology–without being bogged down in programming mechanics.

Object-oriented programming provides powerful assistance for the KBS developer. It has been found to be an effective aid to the *exploratory programming* style that characterizes the incremental refinement process of KBS development. One of the primary problems facing the KBS developer is management of complexity in a dynamic environment. This is increasingly true as KBSs are scaled-up to meet the demands of real-world problems. A powerful aid to managing complexity is a clear conceptual model of the evolving system–a kind of computational skeleton. In constructing a clear model, it is helpful to organize computation around programming constructs whose internal structure and interrelationships explicitly reflect

those of constructs in the physical world in which the resultant systems are to operate. It is in constructing such models that the object-oriented style excels. Furthermore, the object-oriented style encourages modular code with well-defined interfaces through its use of messages as an invocation form. Inheritance of properties simplifies code-sharing. This leads to more space-efficient code and to ease of maintenance and alteration. In addition–and of primary importance–the use of messages allows many traditional KBS representational paradigms (*e.g.,* rules, constraints) to be encoded as objects and invoked (via messages) in a uniform manner.

A clear model of the evolving system is as important to the domain specialist as it is to the KBS developer. Objects appear to be a natural and understandable knowledge organizing mechanism to humans not normally involved in computation. The concept of a *prototype* for encapsulating information–both data and procedures–is well-understood and used by humans, as are the concepts of classes and instances, taxonomies–and taxonomic inheritance of properties (along with a number of other forms of inheritance). In addition, a number of powerful systems have been developed for easy graphical examination and extension of knowledge bases. A keynote to these systems is that the domain specialist is able to express himself and interact in the natural terms and notation of his domain.

In the first part of the presentation, we review our experience with an example of an integrated knowledge-based system development environment based on an object-oriented substrate and demonstrate the advantages of the approach.

We have been discussing the utility of an object-oriented substrate for reducing the knowledge acquisition bottleneck by increasing the bandwidth of interactions between domain specialist, knowledge engineer, and knowledge-based system. There are two intended effects: *(i)* a reduction in the time/cost required for KBS construction and maintenance; and *(ii)* an increase in the robustness and power of the resultant systems. There is a third potential payoff that might accrue from the use of objects as a representational substrate. We are searching for a representational substrate that will allow knowledge to be encoded in such a way as to permit knowledge bases developed in the context of one application to be used almost *as is* in related applications in the same domain. Indeed some aspects of the encoded knowledge bases should be usable across domains. In the short term, this would enable amortization of the cost of knowledge acquisition. In the longer term, it could lead to knowledge-sharing between specialists–a kind of *computational publication*. Unlike the knowledge involved in traditional journal publication, however, this knowledge will be computationally described, directly usable knowledge. Such a development could have enormous implications and could vastly increase the leverage of an individual domain specialist. It could greatly shorten the time delays currently involved in making a new development the widely used standard practice.

In order to obtain the desired effect, we believe that architectural principles of knowledge-based system design must emerge. The current practice in the field will not lead to the advantages we seek regarding robustness, power, and cost of construction and maintenance. Below, we list some candidate principles.

- A clear, expressive domain model is central.
- It is desirable to encode knowledge through abstract relations that are usable across domains (*e.g.,* part/whole, generalization/specialization, task/subtask).
- Knowledge should be partitioned wherever possible (*e.g.,* into domain-independent, domain-specific, and task-specific packets).
- Assumptions about the context in which knowledge will be used should be minimized.

- Control should be explicitly represented (*i.e.,* strategy knowledge, problem-solving state, and problem-solving history).
- Specialized representations are essential (*e.g.,* objects, rules, constraints, tasks, procedures) for high performance. They must be integrated.
- User interaction should be considered as an integrated component.

In the second part of the presentation, we discuss these principles and the utility of object-oriented programming in following them.

Representation in Knowledge-Based Systems

Reid G. Smith

Schlumberger-Doll Research
Old Quarry Road
Ridgefield CT, 06877-4108
USA

Themes

- **State of the art knowledge-based systems orchestrate multiple representational paradigms**
- **An object-oriented substrate offers useful tools for integration of the different paradigms**

- **Architectural principles of knowledge-based systems are emerging**
- **An object-oriented substrate helps developers follow the principles**

Impacting
the
Knowledge Acquisition Bottleneck

KNOWLEDGE ENGINEERING TOOLS

- **Assist the Knowledge Engineer and Domain Specialist to Focus on the Domain Knowledge and Problem-Solving Methodology**
- **Simplify the Incremental Refinement Process**
- **Allow Direct Interaction by the Domain Specialist**

… Expression and Interaction in Domain Terms

- **Amortize KB Construction Cost via Knowledge Sharing**

… Architectural Principles

MACHINE LEARNING TECHNIQUES

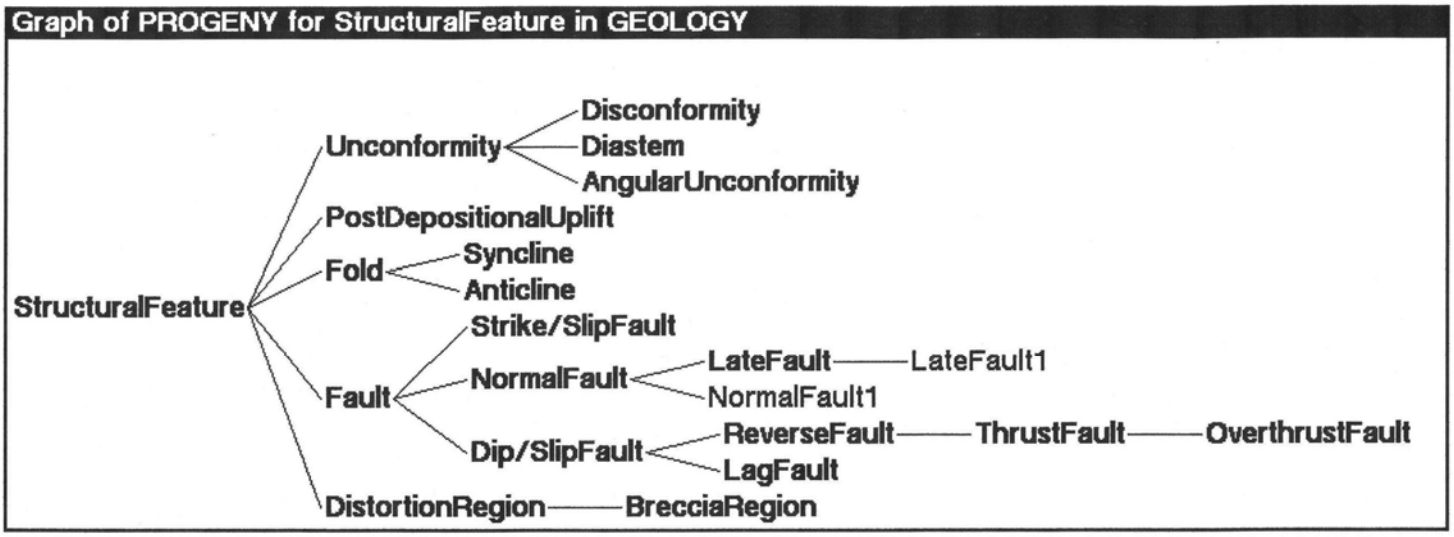
- **Learning Apprentice Systems**

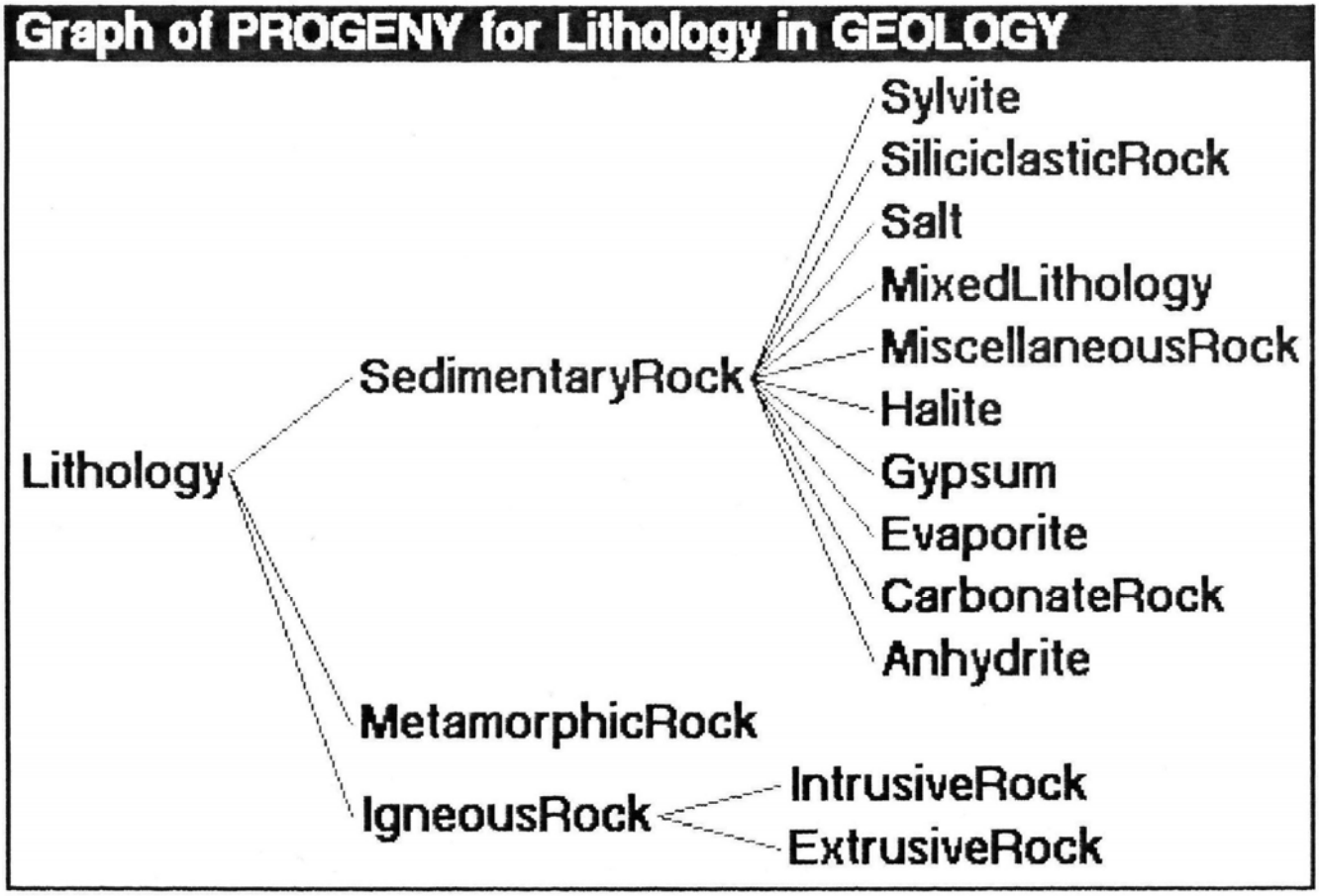
Structured Object Representation

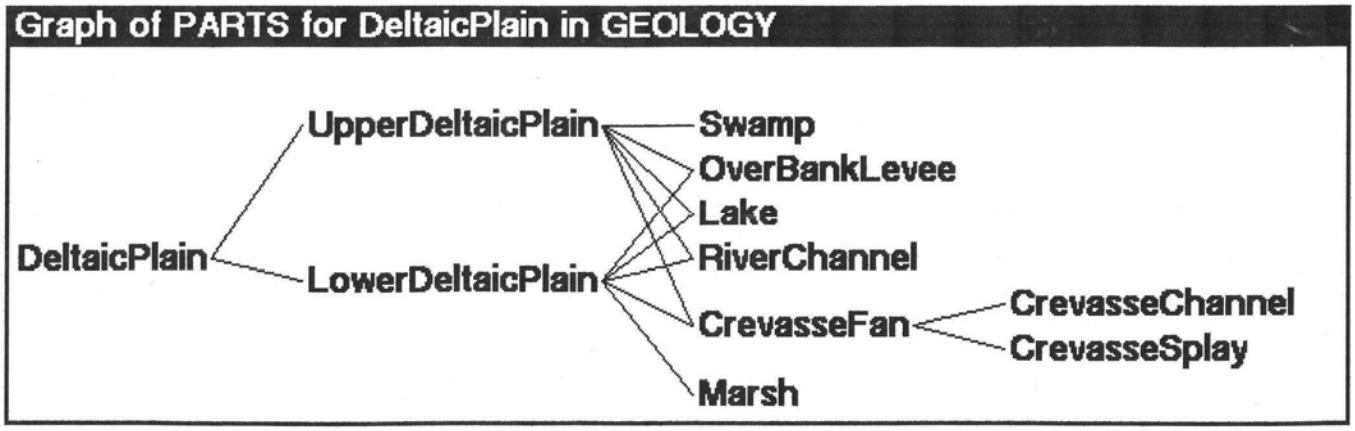
- **Modularity: Encapsulation of Properties and Behavior**
- **Specialized Procedure Invocation via Messages**
- **Abstraction: Taxonomic Hierarchies…**
  - **Inheritance of Properties**
- **Event-Driven Procedure Invocation**

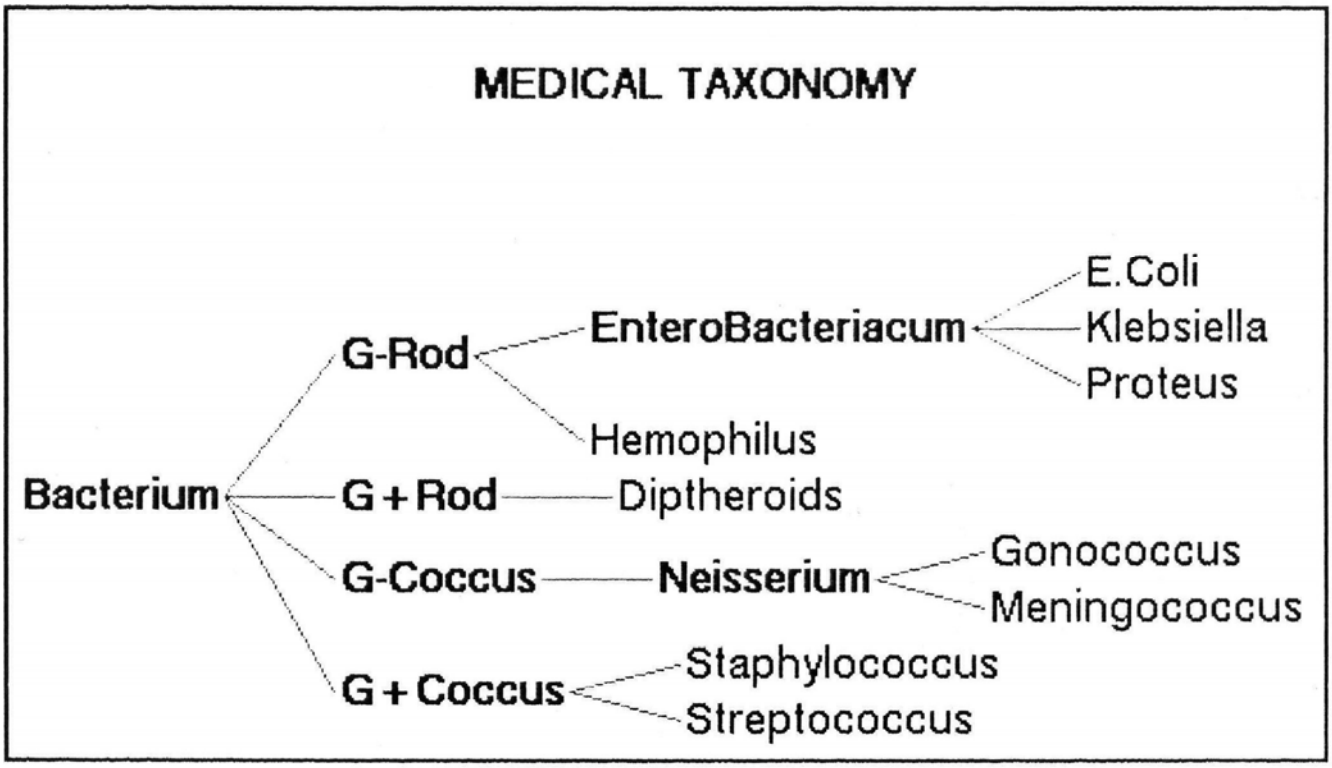
… Useful for Managing Complexity

- **Prototypes: a Natural and Understandable Knowledge Organizing Mechanism**
- **Computational Skeleton: Structure for the Reasoning System**
- **Messages: a Universal Invocation Mechanism**

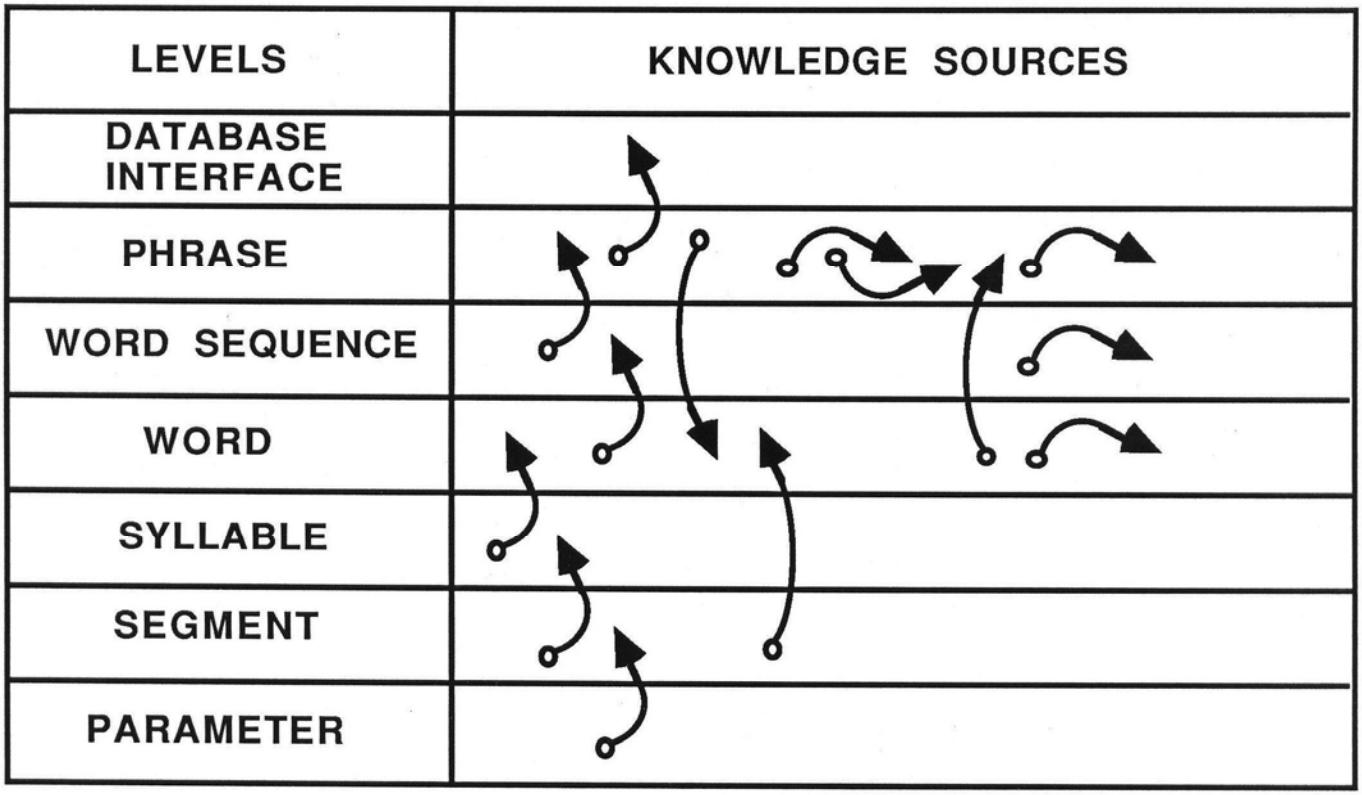

Graph of PROGENY for StructuralFeature in GEOLOGY
StructuralFeature
Unconformity
Disconformity
Diastem
AngularUnconformity
PostDepositionalUplift
Fold
Syncline
Anticline
Fault
Strike/SlipFault
NormalFault
LateFault
LateFault1
NormalFault1
Dip/SlipFault
ReverseFault
ThrustFault
OverthrustFault
LagFault
DistortionRegion
BrecciaRegion

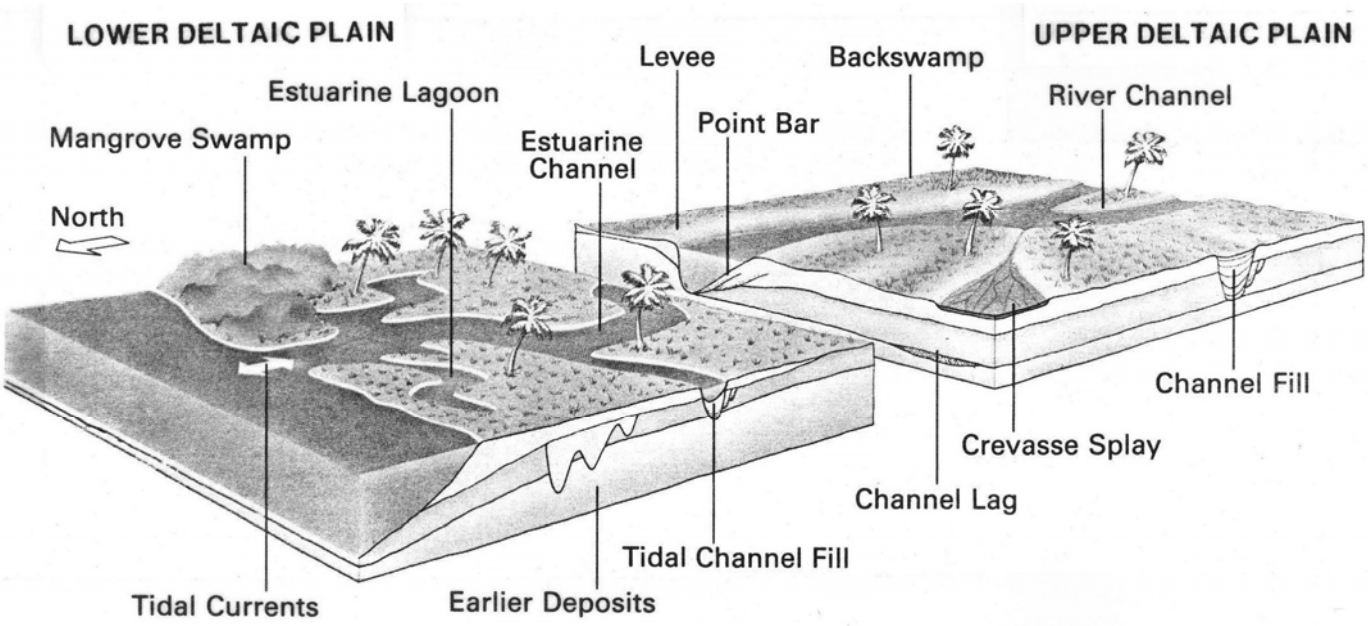

Graph of PROGENY for Lithology in GEOLOGY
Lithology
SedimentaryRock
Sylvite
SiliciclasticRock
Salt
MixedLithology
MiscellaneousRock
Halite
Gypsum
Evaporite
CarbonateRock
Anhydrite
MetamorphicRock
IgneousRock
IntrusiveRock
ExtrusiveRock


Graph of PARTS for DeltaicPlain in GEOLOGY
DeltaicPlain
UpperDeltaicPlain
LowerDeltaicPlain
Swamp
OverBankLevee
Lake
RiverChannel
CrevasseFan
Marsh
CrevasseChannel
CrevasseSplay

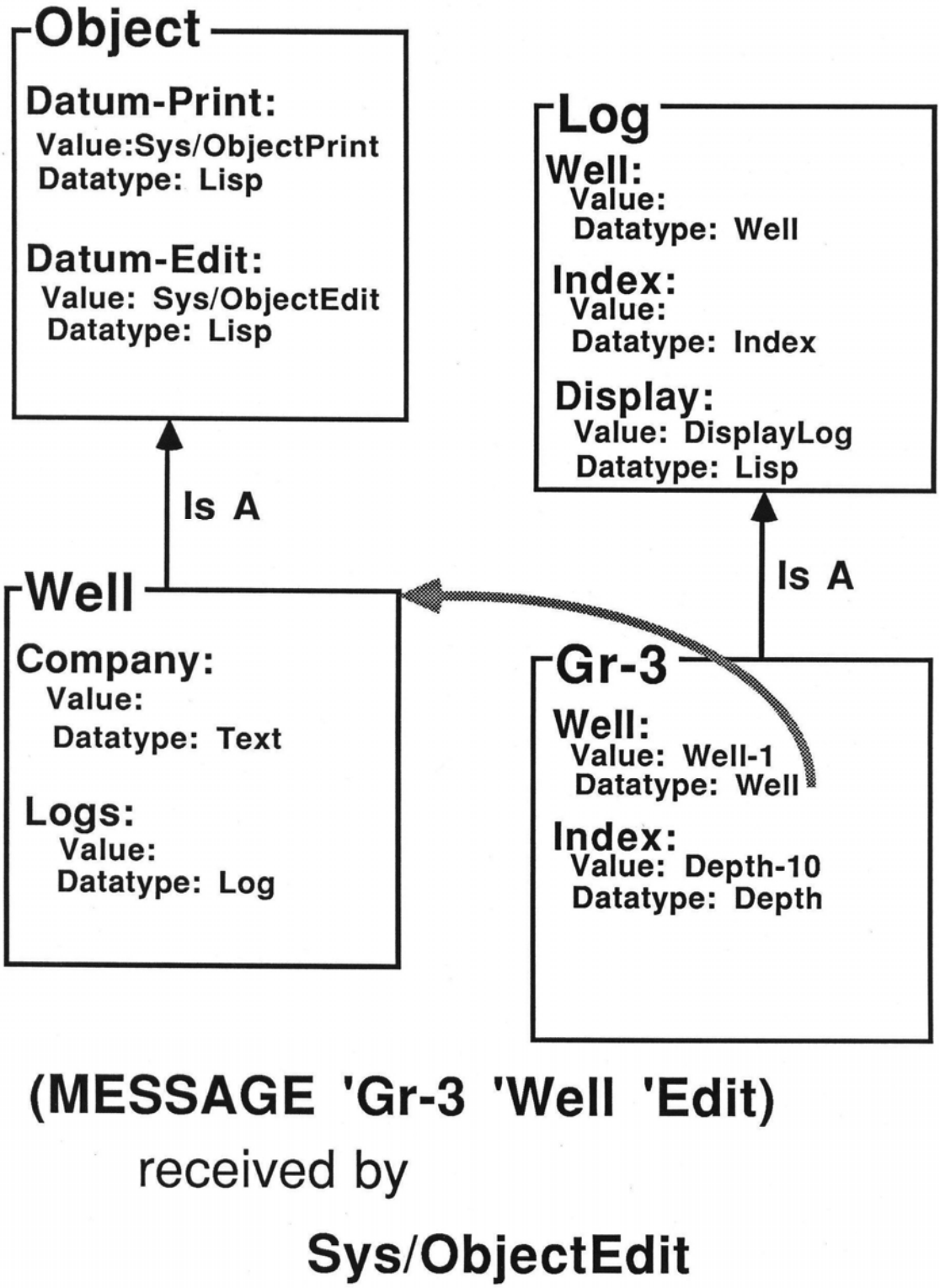

MEDICAL TAXONOMY
Bacterium
G-Rod
EnteroBacteriacum
E.Coli
Klebsiella
Proteus
Hemophilus
G+Rod
Diptheroids
G-Coccus
Neisserium
Gonococcus
Meningococcus
G+Coccus
Staphylococcus
Streptococcus

Hearsay II

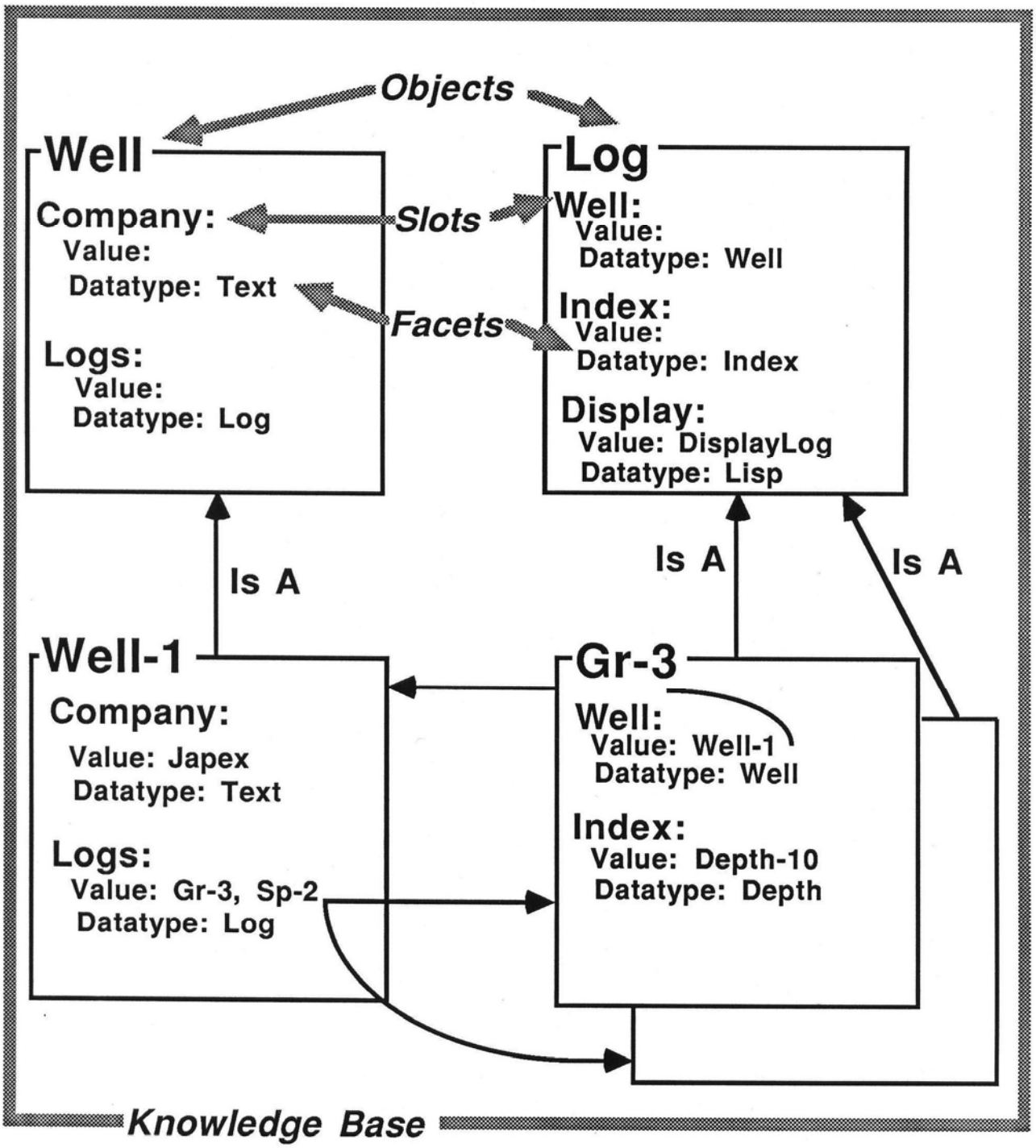

LEVELS
KNOWLEDGE SOURCES
DATABASE INTERFACE
PHRASE
WORD SEQUENCE
WORD
SYLLABLE
SEGMENT
PARAMETER


LOWER DELTAIC PLAIN
UPPER DELTAIC PLAIN
Levee
Backswamp
Estuarine Lagoon
River Channel
Point Bar
Mangrove Swamp
Estuarine Channel
North
Channel Fill
Crevasse Splay
Channel Lag
Tidal Channel Fill
Tidal Currents
Earlier Deposits

Strobe Datatypes



Strobe


Objects
Well
Company:
Value:
Datatype: Text
Logs:
Value:
Datatype: Log
Slots
Facets
Log
Well:
Value:
Datatype: Well
Index:
Value:
Datatype: Index
Display:
Value: DisplayLog
Datatype: Lisp
Is A
Is A
Is A
Well-1
Company:
Value: Japex
Datatype: Text
Logs:
Value: Gr-3, Sp-2
Datatype: Log
Gr-3
Well:
Value: Well-1
Datatype: Well
Index:
Value: Depth-10
Datatype: Depth
Knowledge Base

Strobe Summary

- **Knowledge Bases, Objects, Slots, Facets**
- **Tangled Taxonomic Hierarchies**
  - **Class/Instance Distinction**
  - **Flexible Slot/Facet Inheritance with Caching**
- **Procedural Attachment: Invocation via Message**
  - **Datatype Forwarding**
- **Event-Driven Procedure Invocation**
  - **Object/Slot Creation/Deletion**
  - **Slot Value Access/Alteration [before/after]**
- **Groups: Arbitrary Object Collections**
- **Multiple Resident Knowledge Bases**
- **Multiple Machine/Language Operation**
- **Object/Slot Synonyms**
- **Description Object Instantiation**

Individual Rule Object

Object: NormalFault9
Generalizations: Rule
If: (Condition1 Condition2)
Then: (Action1 Action2)
Condition1: (ThereExists z NormalFaultZone)
Condition2: (ThereExists p RedPattern
($< p.Length RedLength)
($Above p z)
($Perpendicular p.Azimuth z.Strike))
Action1: ($Specialize z 'LateFaultZone)
Action2: ($Assign 'DirectionToDownthrownBlock z
p.Azimuth)
Translation:

If

1. there exists an instance of the class
   NormalFaultZone (z), and
2. there exists an instance of the class RedPattern (p)
   such that the Length of p < RedLength, and
   such that p is above z, and
   such that the Azimuth of p is perpendicular to the
   Strike of z

Then

1. specialize z to be a LateFaultZone
2. the DirectionToDownthrownBlock of z
   ← the Azimuth of p

Individual Rule Object

Object: Tidal1
Generalizations: Rule

...

Translation:

If

1. there exists a Transition/InnerShelfZone (z)
   such that the influence of z is Wave/Tide, and
2. there exists *a set* of BluePatterns (p)
   such that each new element of p is within z, and
   such that each new element of p is below the last element of p, and
   such that the Azimuth of each new element of p is opposite to the Azimuth the last element of p, and
   such that the size of the set p > 1

Then

1. create a TidalFlatZone (tz)
2. the Top of tz ← the Depth of the first element of p
3. the Bottom of tz ← the Depth of the last element of p
4. the Axis of tz ← the Azimuth of the last element of p

Rule Class Object

Object: Rule
Generalizations: Object

If:
Then:
Ruleset:
Translation:
Apply: ApplyRule
Match: MatchRule
MatchAll: MatchRuleAll
Execute: ExecuteRule
Translate: TranslateRule

Individual Ruleset Object

Object: DeepMarineRuleset
Generalizations: Ruleset
NormalRules: Marine-20 Marine-21 Marine-22
ControlStrategy: ReStartAfterFiring

Ruleset Class Object

Object: Ruleset
Generalizations: Object
NormalRules:
FireOnceRules:
FireAlwaysRules:
ControlStrategy:
Termination Condition:
KnowledgeBase:
Apply: ApplyRuleset
ApplyInProcess: ApplyRulesetInProcess

Constrained Object

Object: WellLocation
Type: Class
Generalizations: Object

Well:
TOWN: {Township}
STAT: {State Province}
NATI: {Nation Country}
CONT: {Continent}
Value:
Datatype: Expr
Candidates: (Europe North-America South-America Asia Africa Australia)
Constraints: (MembershipConstraint)

Single Slot Constraint Object

Object: MembershipConstraint
Generalizations: SingleSlotConstraint

If {Condition}: (Condition1)
Then {Correction}: (Action1)
Condition1: (NOT (MEMBER Value Candidates))
Action1: (ERROR Value "is not one of:" Candidates)

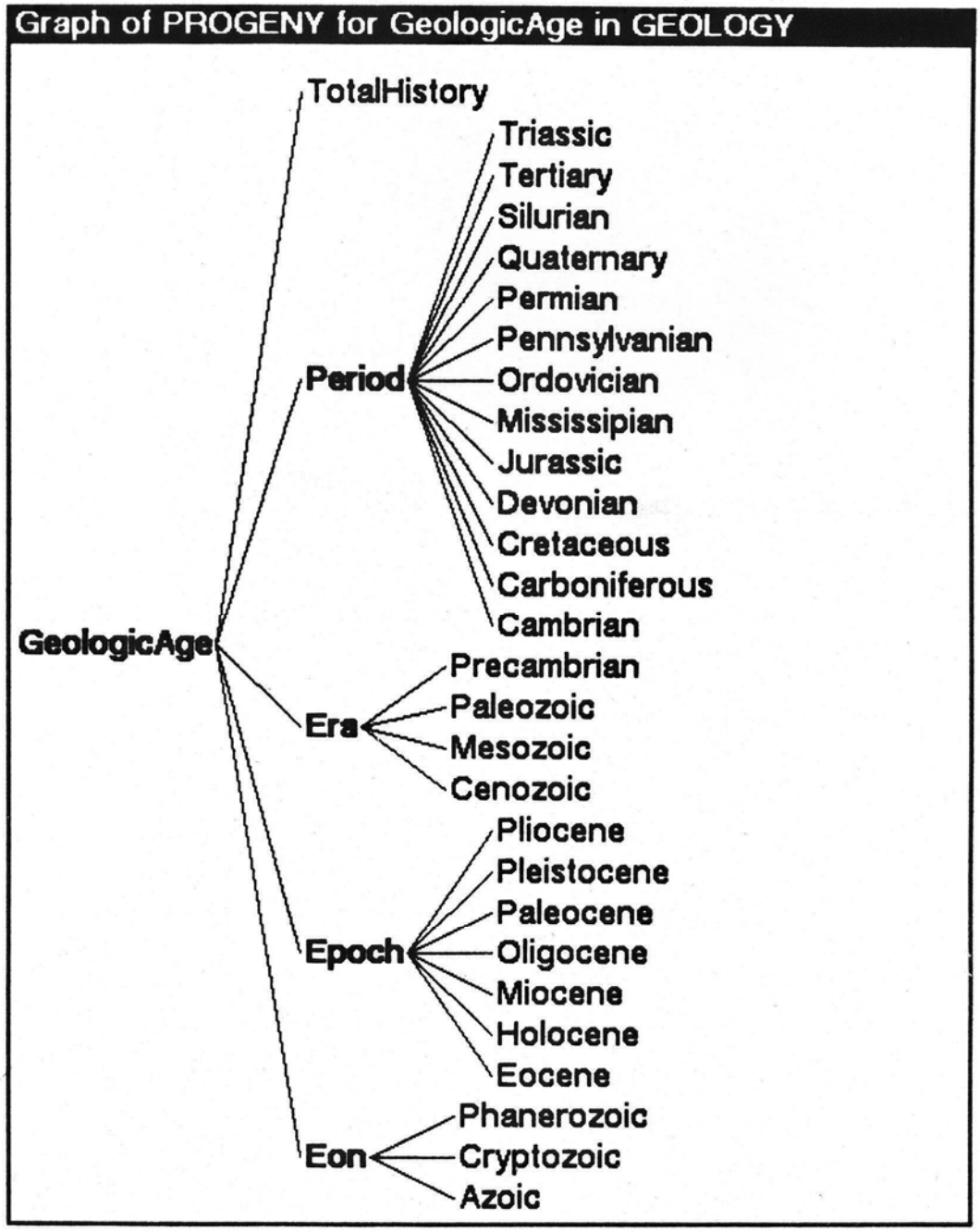
SetOrElementConstraint: Element

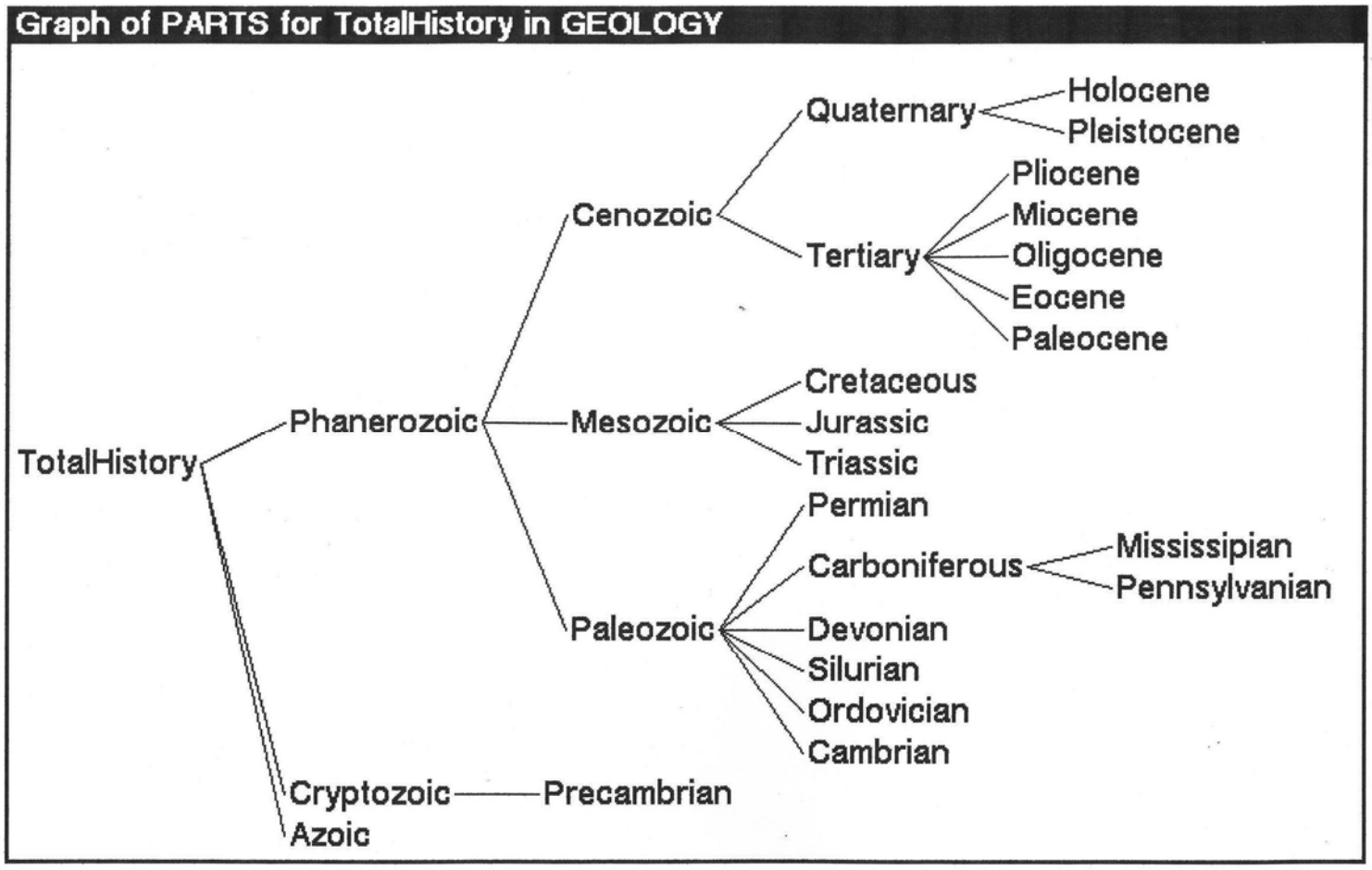
Datatype Object for Integrity

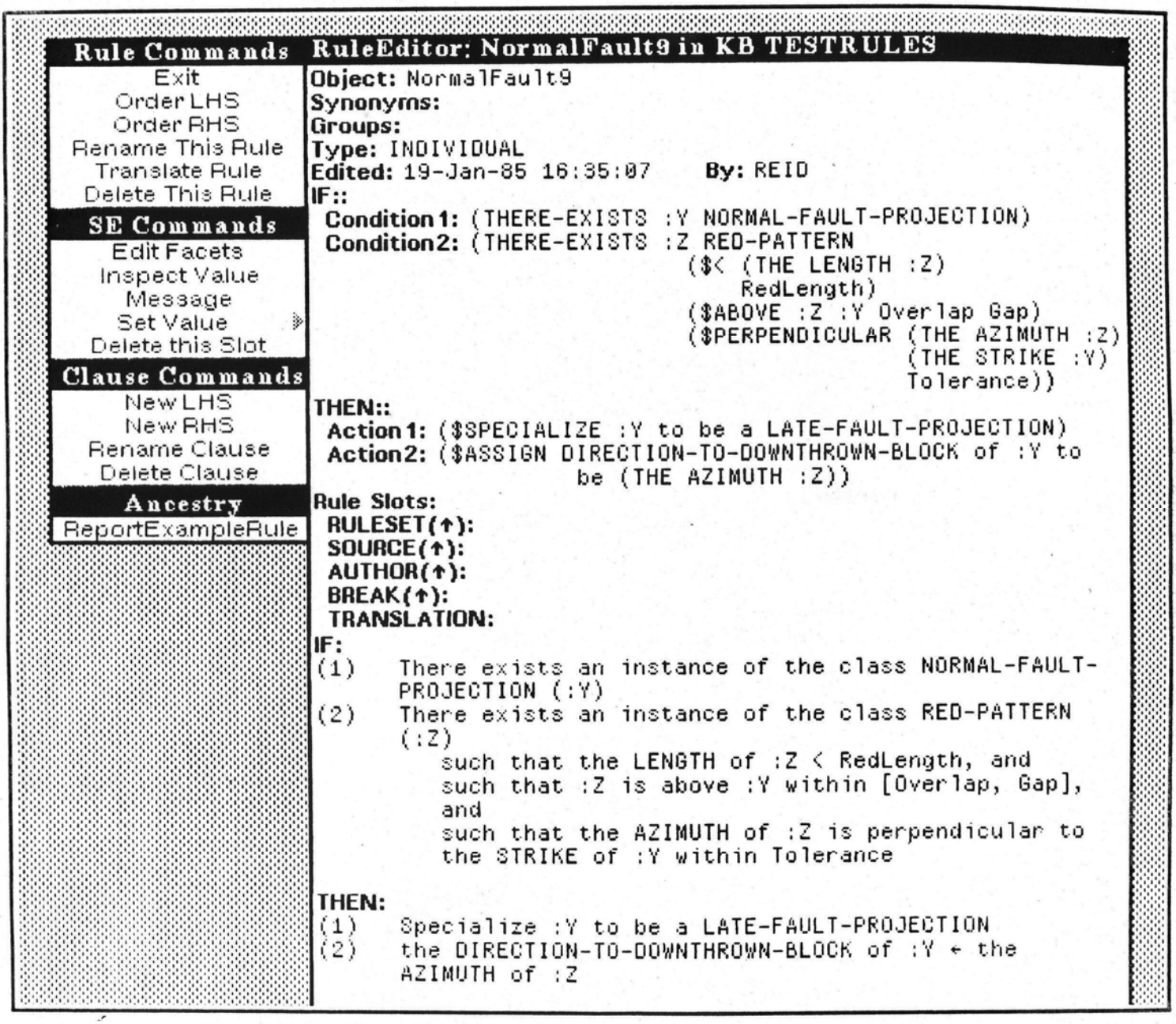
Object: Datatype
Generalizations: Root
Datum-Get: StandardGetHandler
…
Datum-Put: IntegrityPutHandler
Datum-Add: IntegrityAddHandler
Datum-Remove: IntegrityRemoveHandler
…

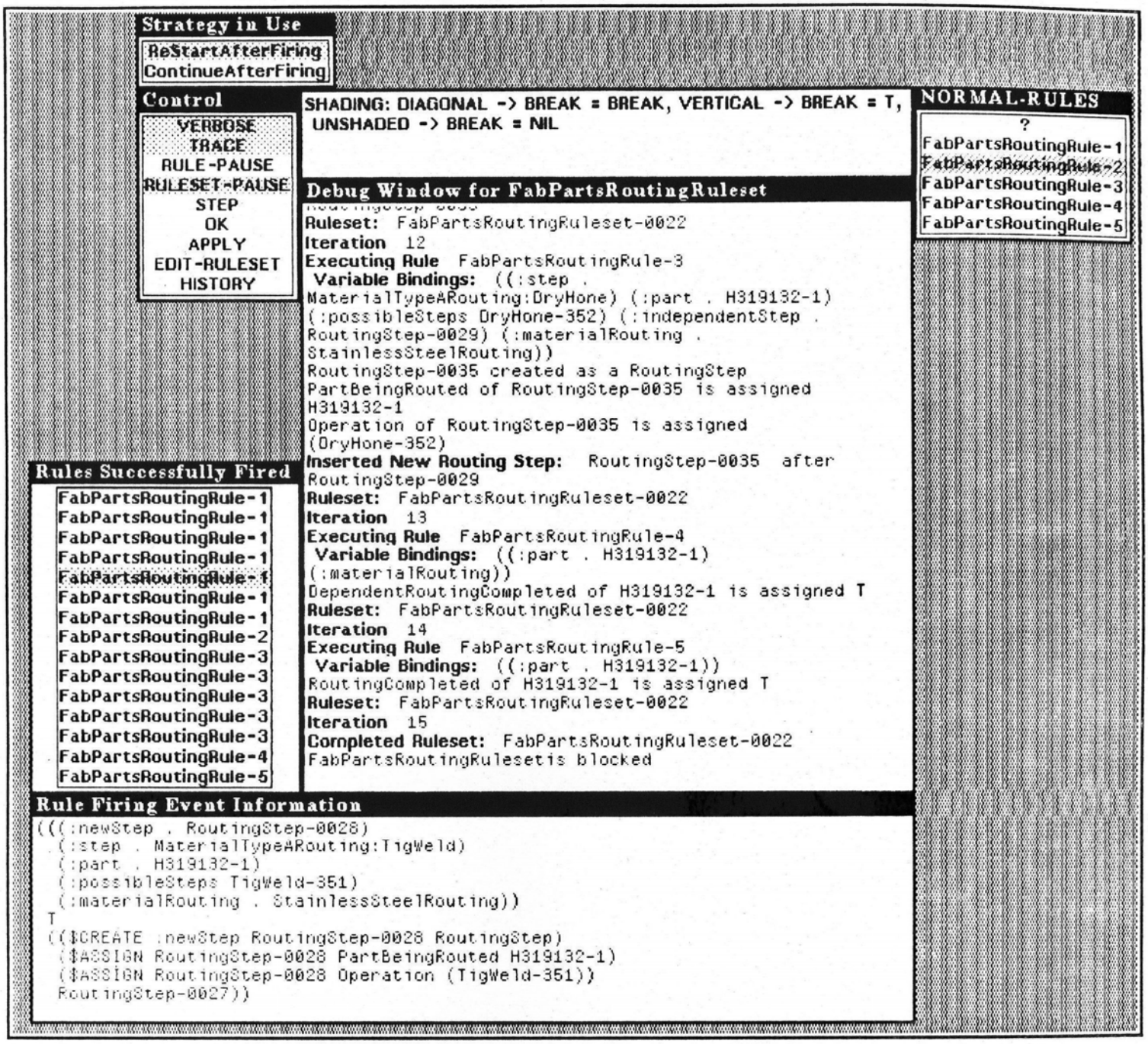
Impulse: An Extensible and Interactive Knowledge Base Editor

- **Reactive Environment**
- **Customized Presentation and Interaction**
- **Flexible Display of Knowledge Base Structure**


Graph of PROGENY for GeologicAge in GEOLOGY
GeologicAge
TotalHistory
Period
Triassic
Tertiary
Silurian
Quaternary
Permian
Pennsylvanian
Ordovician
Mississipian
Jurassic
Devonian
Cretaceous
Carboniferous
Cambrian
Era
Precambrian
Paleozoic
Mesozoic
Cenozoic
Epoch
Pliocene
Pleistocene
Paleocene
Oligocene
Miocene
Holocene
Eocene
Eon
Phanerozoic
Cryptozoic
Azoic


Graph of PARTS for TotalHistory in GEOLOGY
TotalHistory
Phanerozoic
Cryptozoic
Azoic
Precambrian
Cenozoic
Mesozoic
Paleozoic
Quaternary
Tertiary
Holocene
Pleistocene
Pliocene
Miocene
Oligocene
Eocene
Paleocene
Cretaceous
Jurassic
Triassic
Permian
Carboniferous
Devonian
Silurian
Ordovician
Cambrian
Mississipian
Pennsylvanian

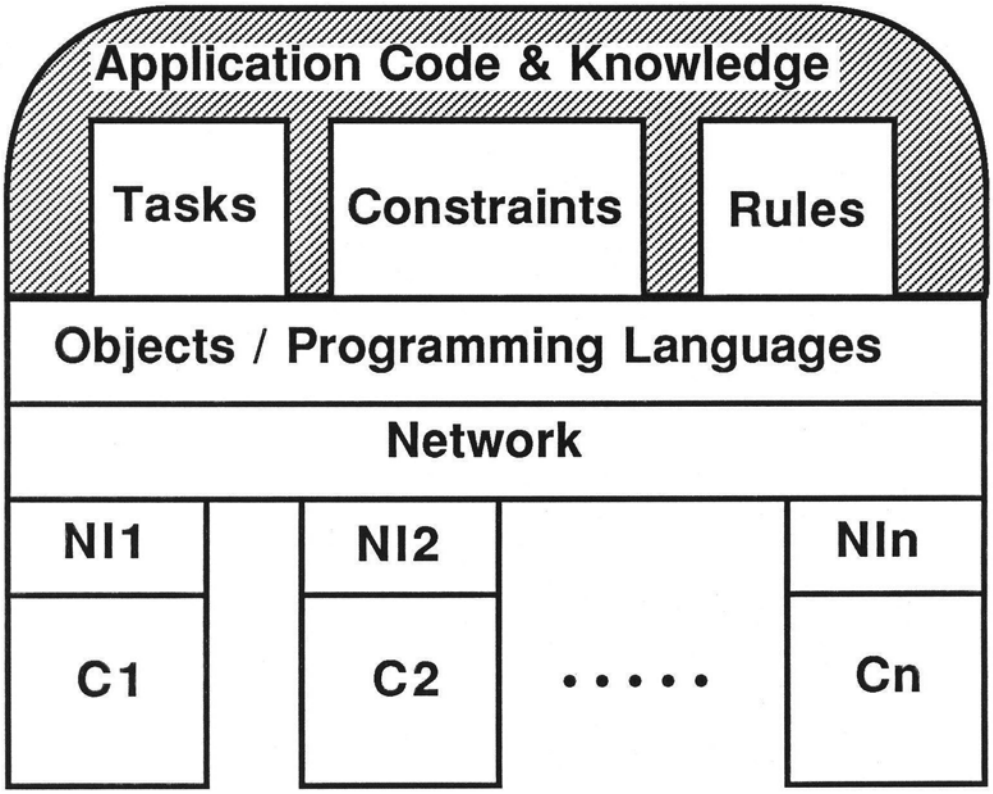

Rule Commands
Exit
Order LHS
Order RHS
Rename This Rule
Translate Rule
Delete This Rule
SE Commands
Edit Facets
Inspect Value
Message
Set Value
Delete this Slot
Clause Commands
New LHS
New RHS
Rename Clause
Delete Clause
Ancestry
ReportExampleRule
RuleEditor: NormalFault9 in KB TESTRULES
Object: NormalFault9
Synonyms:
Groups:
Type: INDIVIDUAL
Edited: 19-Jan-85 16:35:07 By: REID
IF::
Condition1: (THERE-EXISTS :Y NORMAL-FAULT-PROJECTION)
Condition2: (THERE-EXISTS :Z RED-PATTERN
($< (THE LENGTH :Z)
RedLength)
($ABOVE :Z :Y Overlap Gap)
($PERPENDICULAR (THE AZIMUTH :Z)
(THE STRIKE :Y)
Tolerance))
THEN::
Action1: ($SPECIALIZE :Y to be a LATE-FAULT-PROJECTION)
Action2: ($ASSIGN DIRECTION-TO-DOWNTHROWN-BLOCK of :Y to
be (THE AZIMUTH :Z))
Rule Slots:
RULESET(↑):
SOURCE(↑):
AUTHOR(↑):
BREAK(↑):
TRANSLATION:
IF:
(1) There exists an instance of the class NORMAL-FAULT-PROJECTION (:Y)
(2) There exists an instance of the class RED-PATTERN (:Z)
such that the LENGTH of :Z < RedLength, and
such that :Z is above :Y within [Overlap, Gap], and
such that the AZIMUTH of :Z is perpendicular to the STRIKE of :Y within Tolerance
THEN:
(1) Specialize :Y to be a LATE-FAULT-PROJECTION
(2) the DIRECTION-TO-DOWNTHROWN-BLOCK of :Y ← the AZIMUTH of :Z


Strategy in Use
ReStartAfterFiring
ContinueAfterFiring
Control
VERBOSE
TRACE
RULE-PAUSE
RULESET-PAUSE
STEP
OK
APPLY
EDIT-RULESET
HISTORY
SHADING: DIAGONAL -> BREAK = BREAK, VERTICAL -> BREAK = T, UNSHADED -> BREAK = NIL
NORMAL-RULES
?
FabPartsRoutingRule-1
FabPartsRoutingRule-2
FabPartsRoutingRule-3
FabPartsRoutingRule-4
FabPartsRoutingRule-5
Debug Window for FabPartsRoutingRuleset
Ruleset: FabPartsRoutingRuleset-0022
Iteration 12
Executing Rule FabPartsRoutingRule-3
Variable Bindings: ((:step . MaterialTypeARouting:DryHone) (:part . H319132-1) (:possibleSteps DryHone-352) (:independentStep . RoutingStep-0029) (:materialRouting . StainlessSteelRouting))
RoutingStep-0035 created as a RoutingStep
PartBeingRouted of RoutingStep-0035 is assigned H319132-1
Operation of RoutingStep-0035 is assigned (DryHone-352)
Inserted New Routing Step: RoutingStep-0035 after RoutingStep-0029
Ruleset: FabPartsRoutingRuleset-0022
Iteration 13
Executing Rule FabPartsRoutingRule-4
Variable Bindings: ((:part . H319132-1) (:materialRouting))
DependentRoutingCompleted of H319132-1 is assigned T
Ruleset: FabPartsRoutingRuleset-0022
Iteration 14
Executing Rule FabPartsRoutingRule-5
Variable Bindings: ((:part . H319132-1))
RoutingCompleted of H319132-1 is assigned T
Ruleset: FabPartsRoutingRuleset-0022
Iteration 15
Completed Ruleset: FabPartsRoutingRuleset-0022
FabPartsRoutingRulesetis blocked
Rules Successfully Fired
FabPartsRoutingRule-1
FabPartsRoutingRule-1
FabPartsRoutingRule-1
FabPartsRoutingRule-1
FabPartsRoutingRule-1
FabPartsRoutingRule-1
FabPartsRoutingRule-1
FabPartsRoutingRule-2
FabPartsRoutingRule-3
FabPartsRoutingRule-3
FabPartsRoutingRule-3
FabPartsRoutingRule-3
FabPartsRoutingRule-3
FabPartsRoutingRule-4
FabPartsRoutingRule-5
Rule Firing Event Information
(((:newStep . RoutingStep-0028)
(:step . MaterialTypeARouting:TigWeld)
(:part . H319132-1)
(:possibleSteps TigWeld-351)
(:materialRouting . StainlessSteelRouting))
T
(($CREATE :newStep RoutingStep-0028 RoutingStep)
($ASSIGN RoutingStep-0028 PartBeingRouted H319132-1)
($ASSIGN RoutingStep-0028 Operation (TigWeld-351))
RoutingStep-0027))

MODULAR INCREMENTS TO *STROBE*

- ***Impulse***
  - **Strobe-based KB editor**
  - **Customizable**
- **Rule Interpreter**
  - **Rule Debugging Package**
  - **Rule Editor (Impulse-based)**
- **Constraint Package**
  - **Semantic Integrity Management within and among objects**
- **Object File Management (KBMS)**
  - **Indexed non-resident object files**
- **Declarative Task Representation**
  - **Control and data flow among modules**
  - **User-interface information**

SUBSTRATES


Application Code & Knowledge
Tasks
Constraints
Rules
Objects / Programming Languages
Network
NI1
NI2
NIn
C1
C2
• • • • •
Cn

KBS Architectural Principles

(Davis, 1982)

Separate the Inference Engine and Knowledge Base

- **What Is True vs How to Use It**

Use as Uniform a Representation as Possible

- **Specialization Is Often Worth the Cost of Translation**

Keep the Inference Engine Simple

Exploit Redundancy

KBS Architectural Principles

A Clear, Expressive Domain Model is Central

- Objects
- Abstract Relations

Partition Knowledge Wherever Possible

- Domain-Independent Knowledge
- Domain-Specific Knowledge
- Task-Specific Knowledge

Avoid Assumptions about Context of Use

Represent Control Explicitly

- Strategy Knowledge
- Problem-Solving State

Orchestrate Multiple Representations

- Objects, Rules, Procedures
- Invocation via Message

Consider User Interaction as an Integrated Component

Encoding Abstract Relations

- **Generalization**
  - **Specialization**
  - **Subsumption**
- **Class Membership**
- **SuperPart** **Task** **Abstraction**
  - **Part** **Subtask** **Expansion**
  - **Port …**
- **Cause**
  - **Effect**
  - **Manifestation**
- **Suggests**
- **Precondition**
  - **Postcondition**
- **Ordering …**
- **Attribute (obligatory, optional, …)**
  (necessary, sufficient, …)

Control Rule

Create tasks to determine any unknown attributes of the focus of the current task (one task per attribute).

If

There exists an *Attribute* (:att) of the *Focus (:f)*
of the ***Current Task***
such that the :att of :f is unknown, and
such that there are *Detectors* (:dtr) of :att of :f

Then

Create a Sibling Task (:st) of the ***Current Task***
To Detect :att of :f using :dtr
Append [Rules ReElaborate Apply] to the
SuccessfullnvocationProcessors of :sbt

Abstraction Example

(Szolovits & Clancey, 1985)

If **Mary has a fever,**
then **Mary has an infection.**

Mary is a patient

If **the patient has a fever,**
then **the patient has an infection.**

Fever is a symptom. Infection is a disease.
Fever is a symptom of infection.

If **the patient has a symptom of a disease,**
then **the patient has the disease.**

A symptom is a feature. A disease is a class.

If **there is evidence for a feature of a class,**
then **there is evidence for the class.**

Interpretation Rule

Recognize the existence of a **CrevasseSplay.**

If

There exists a **RockUnit** (:ru) in the ***Current Context***
such that the *DepositionalEnvironment* (:de) of :ru
is a descendant of **CrevasseFan**, and
There exists an element of the *Patterns* (:bp) of :ru
such that :bp is an instance of **BluePattern**, and
such that at least 0.8 of :bp is within :ru, and
There does not exist a co-constituent of :ru (:ru2)
such that the *DepositionalEnvironment* of :ru2
is a descendant of **ChannelLag**, and
such that :ru2 is below :ru

Then

Alter :de of :ru to be **CrevasseSplay**

Interpretation Rule

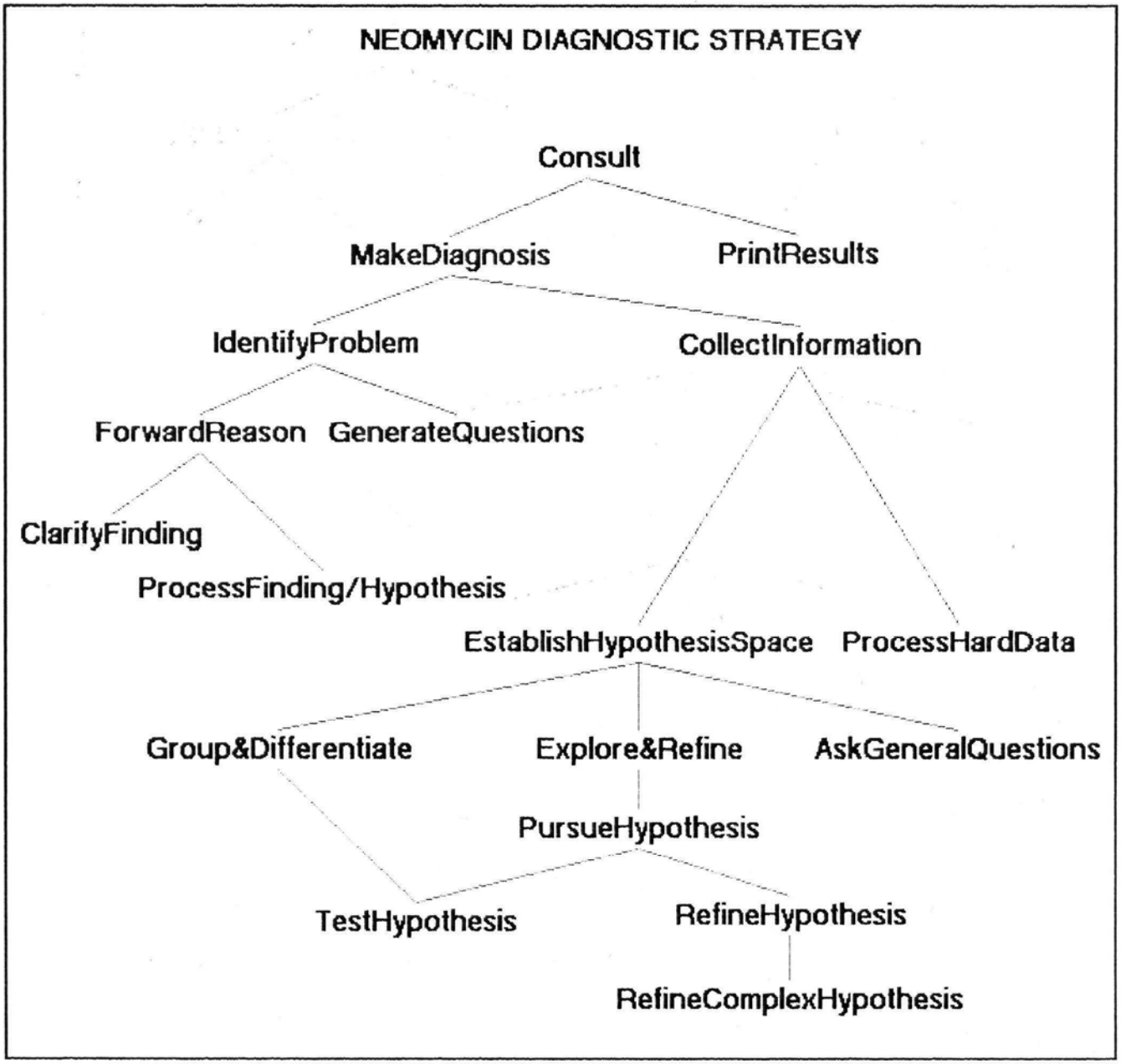
Recognize the existence of a **CrevasseSplay.**

If

There exists a **RockUnit** (:ru) in the ***Current Context***
such that the *DepositionalEnvironment* (:de) of :ru
is a descendant of **CrevasseFan**, and
There exists an element of the *SedimentaryFeatures* (:cb) of :ru
such that :sf is an instance of **CurrentBedding**, and
such that at least 0.8 of :cb is within :ru, and
There does not exist a co-constituent of :ru (:ru2)
such that the *DepositionalEnvironment* of :ru2
is a descendant of **ChannelLag**, and
such that :ru2 is below :ru

Then

Alter :de of :ru to be **CrevasseSplay**


NEOMYCIN DIAGNOSTIC STRATEGY
Consult
MakeDiagnosis
PrintResults
IdentifyProblem
CollectInformation
ForwardReason
GenerateQuestions
ClarifyFinding
ProcessFinding/Hypothesis
EstablishHypothesisSpace
ProcessHardData
Group&Differentiate
Explore&Refine
AskGeneralQuestions
PursueHypothesis
TestHypothesis
RefineHypothesis
RefineComplexHypothesis

Examples:

IF the hypothesis being focused upon has a child that has not been pursued

THEN pursue that child

IF there is a datum that can be requested that is a characterizing feature of the recent finding that is currently being considered

THEN find out about the datum

IF the desired finding is a subtype of a class of findings, and
the class of findings is not present in this case

THEN conclude that the desired finding is not present

Control Rule

Create tasks to elaborate the attribute values of the focus of the current task (one task per attribute value).

If

There exists a local *Attribute* (:att) of the *Focus* (:f)
of the ***Current Task***
such that :att is known and elaborable

Then

Create an Offspring Task (:ost) of the ***Current Task***
To Elaborate :att using [Rules ReElaborate Apply]
Append [Rules DeActivate Apply] to the
SuccessfullnvocationProcessors of :ost

Control Rule

Create a task to refine the focus of the current task.

If

There does not exist a *Sibling Task* (:tsk) of
the ***Current Task***
such that the Task of :tsk = Refine, and
There exists a *Focus* (:f) of the ***Current Task***
such that the *Refiners* (:r) of :f are known

Then

Create a Sibling Task (:sbt) of the ***Current Task***
To Refine :f using :r
Append [Rules ReEstablishRefine Apply] to the
SuccessfullnvocationProcessors of :sbt

Interpretation Rule

Establish the existence of any *EnergyIndications*.

If

There exists a **RockUnit** (:ru) in the ***Current Context***
such that the *Energyindications* of :ru are unknown,
such that the *Well* (:wl) of :ru is known,
such that the *LogData* (:ld) of :wl is known,
such that Message to
[Detectors, EnergyIndicators, Detect] (:en)
is successful

Then

Assign *EnergyIndications* of :ru to be :en

Advantages:

- **Transparency**
- **Explainability**
- **Maintainability and Extensibility**
    - **Simplified Addition of New Facts and Relations**
    - **Increased Robustness**
- **Storage**
- **Reusability of KBs in Related Domains**
    - **Lower Cost of Construction**
- **Freedom to Select Optimal Representation For Special Cases**